Weeds

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NUMBER 2

Journal of the Association of Regional Weed Control Conferences

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***WEEDS* EMBLEM**

Several readers have wondered about the identity of the plant pictured on our cover and on our letterhead. The plant is a perennial reproducing in typical fashion for this genus. The name is *Artisticum concepcianum* var. *Stephenii*. This particular variety of *Artisticum* is frequently found near Ithaca, New York at altitudes ranging from slightly less than 400 to more than 1700 feet above sea level. It is known by several colloquialisms. We were pleased to get a recent report that what seems to be this same variety is well established in the vicinity of Turrialba and San Jose, Costa Rica. A few have viewed our selection with disapproval because it is actually more beneficial than harmful to most farmers. This group thinks we should have chosen a particularly widespread serious economic pest such as mesquite, thistle, bindweed, or Johnson grass. Don't hesitate to let us have your opinion.

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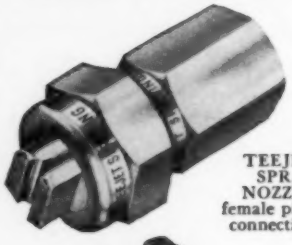

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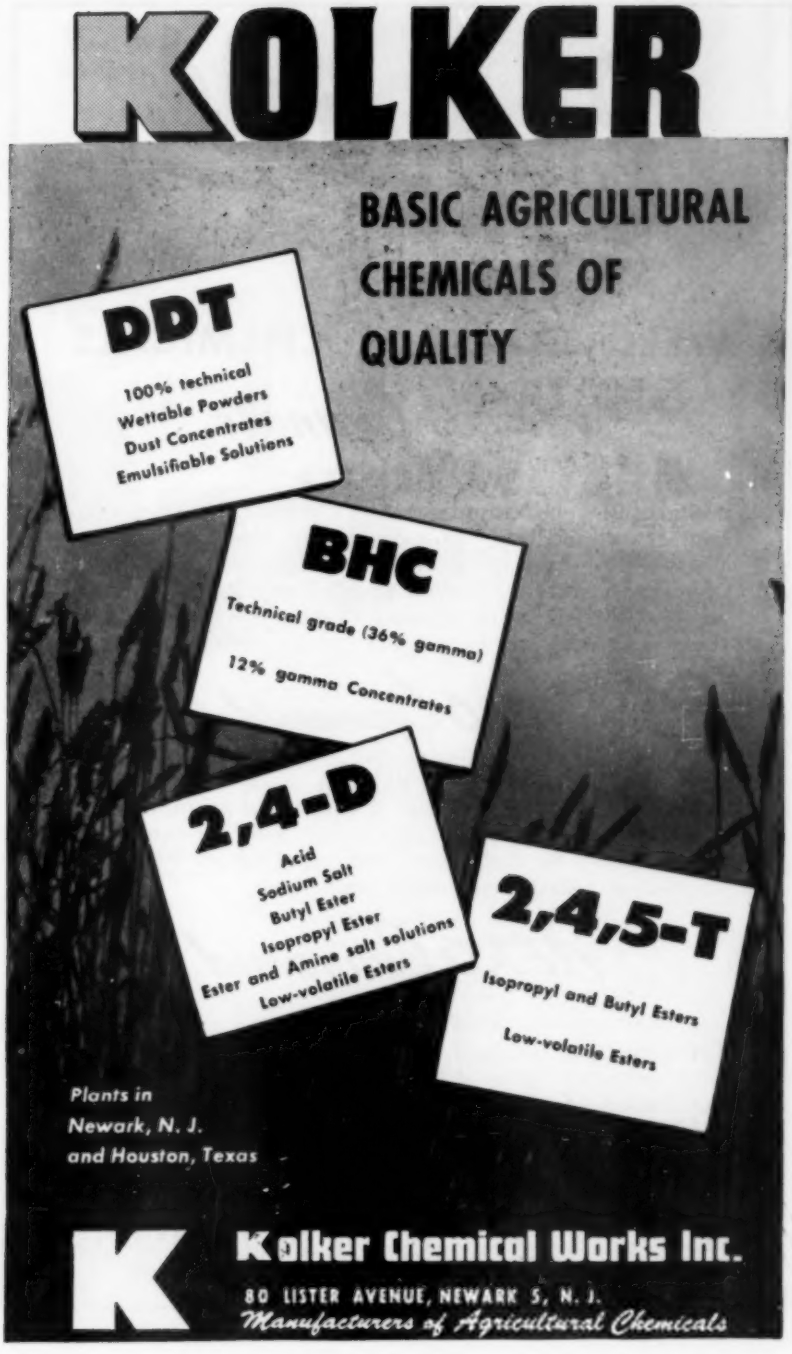
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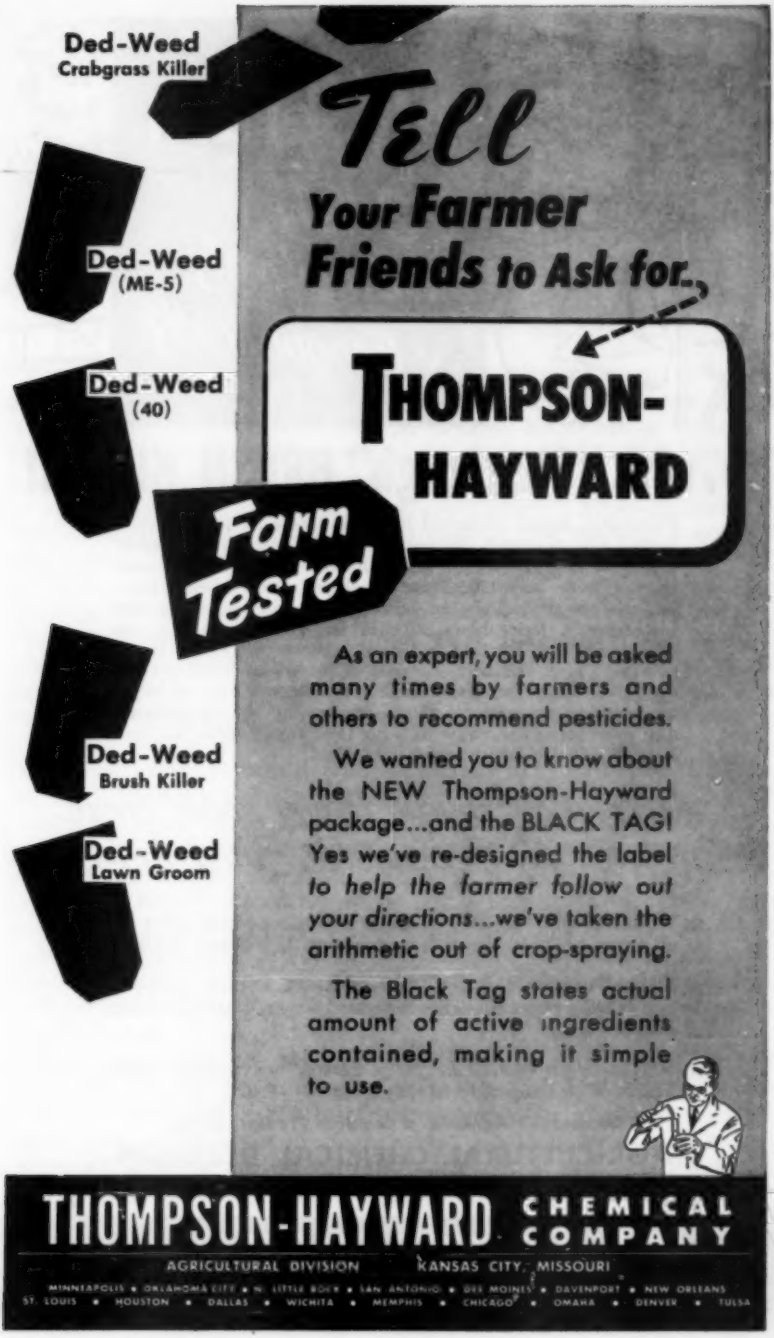
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Weeds

JOURNAL OF THE ASSOCIATION OF REGIONAL WEED CONTROL CONFERENCES.

VOLUME I JANUARY 1952 NUMBER 2

Concerning Authors and Editors

THE EDITORIAL BOARD is having mental pains trying to arrive at a reasonable set of standards for both the length and the content of manuscripts to be published in WEEDS. Your editor thought it would be a fairly simple matter to determine the proper length for a given manuscript on the basis of its content, and to tell whether or not the subject had been adequately treated so as to make the article worthy of publication. To slightly paraphrase a common expression, "How naive can one be?"

There is almost unanimous agreement that the Editorial Board must be the executor of editorial policy, and must make the final decisions as to what to publish and what to reject. When, however, one tries to set forth exactly what the editorial policy shall be the fur begins to fly. After many hours of bull sessions, letters, and phone calls concerning quantity and quality of manuscripts, we seem to have two camps emerging. On the one hand there are those who believe that the manuscript shall be subject to plentiful but judicious use of the editor's pencil; that the editor and reviewers should carefully investigate experimental methods, statistical analyses, and reject all papers not meeting these standards. The other group though, views editors and reviewers as a necessary evil inherent in an author's attempt to have his printed words put before the appropriate audience. Since it is the author's communication to his readers and the latter's acceptance or rejection of that communication which makes "the wheels go 'round" in the publishing business, this school of believers feels editors and reviewers should act only as referees, not as rule-makers.

Many and long are the honest differences which exist between "pro-editor" and "pro-author" groups. There is one very important point, however, which the latter often overlooks when exercising its rights and when resisting manuscript revision by the statement, "after all, it is the author who signs the article and it is the author who will be ridiculed if any 'boners' have been pulled". Although this is true to a certain extent, we should not forget that no journal can afford to print many "boners" or other authors will refuse to submit their works. This ultimately leads to the demise of the journal. An even more insidious situation may arise when "boners" are quoted by speakers or by writers of articles or texts supposedly based on scientific facts. It is in this manner that errors creep into text-

books, because each author cannot be a critical specialist in all the fields covered by the several chapters in his text. An author assumes that if it is printed in a scientific journal it cannot be an error or even open to serious question. Students, of course, follow the same reasoning in reading texts. Thus by trying to be liberal with authors and by scrupulously avoiding anything that would stifle the press, editors may actually retard what they are trying to promote, namely, "increased dissemination of sound scientific facts".

So, Mr. Reader, if you would be kind enough to send in your views, we would be happy to hear from you; and, Mr. Author, please remember there are many ramifications to "Freedom of the press". From both may we continue to have tolerance? In the meantime, your editor is trying to steer down the middle.

A National Weed Meeting

A little less than two years ago the officials of the Association of Regional Weed Control Conferences met in Kansas City. Among other items of business they proposed that the representatives of the several conferences determine what the sentiment was "back home" regarding a national weed meeting.

After careful consideration of the many sides to the problem, the individual conferences are now in the process of voting on the question. As we go to press both the North Central and Northeastern Conferences have voted to (1) support a national meeting, (2) continue their regional conferences on an annual basis. By the time you read these paragraphs the Southern and Western Conferences will have reached a decision.

If the four conferences vote in favor of a national meeting, probably the earliest it could possibly be held would be January or February, 1953. Presumably, the Association of Regional Conferences would shoulder the load of planning and organization, and would delegate the details on local arrangements to a committee located near the chosen site. The Northeastern Conference suggested a midwest location, perhaps Kansas City or St. Louis.

How many would come to a national meeting? How many would it take to finance such a meeting with only a modest registration fee? What type of program would be best? These are samples of the bridges which will have to be crossed if the Southern and Western Conferences vote "yes" to a national meeting.

Weeds will be glad to learn your opinion on a national meeting.

Some Environmental Factors Affecting the Response of Sweet Corn to 2,4–D[1]

GEORGE O. ELLE[2]

Dept. of Vegetable Crops, Cornell University, Ithaca, N. Y.

GENERALLY, 2,4–Dichlorophenoxyacetic acid (2,4–D) has performed well as a selective herbicide for sweet corn. Sometimes, however, applications of 2,4–D presumably at recommended dosages have resulted in abnormal plant behavior. In certain instances reduced yields have resulted.

The purpose of this research was to investigate some of the environmental factors which might influence the response of sweet corn to herbicidal concentrations of 2,4–D.

GENERAL METHODS

Plants of all greenhouse experiments, with one exception, were grown in 1-quart, wood veneer boxes filled with sandy loam soil, two plants per box. In some experiments soil was sub-irrigated by ⅜" glass wicks with two boxes mounted over one No. 10 size asphalt-coated can filled with a modified Hoaglands No. 1 solution. This solution was also applied to surface-irrigated boxes every 4 to 6 days. The sub-irrigation technique proved to be more satisfactory than surface irrigation as it provided optimum moisture conditions at all times, resulting in plants of greater uniformity and vigor whose measurable responses were more distinct and less variable.

A foliage or soil spray of 2,4–D (amine salt) was applied at a rate equivalent to 1 pound per acre. Applications were made with a hand atomizer operating under a constant, automatically regulated pressure of 5 pounds, which resulted in a droplet size of approximately 300 to 700μ range.

At the conclusion of the treatment period of the plants, residual 2,4–D was removed from the foliage by directing a spray of water from a fine-spray hose nozzle over the leaves and rubbing them gently between the fingers. Precaution was taken to prevent leachate from coming in contact with the soil.

Controlled temperature, relative humidity, and light intensity studies were conducted in chambers where maximum light intensities at the plant level (1100–1200 foot candles) were found to be adequate for vigorous, sustained plant growth. A uniform photoperiod of 14 hours was used in the chambers. Minimum fresh air intake was about 100 cubic feet per hour, which, when calculated on the basis of plant size used, provided an atmosphere in excess of 0.001 per cent CO_2 at all times.

Carmelcross proved to be an excellent test variety because it gave

[1]Paper No. 341 of the Department of Vegetable Crops, Cornell Univ., Ithaca, N. Y.

[2]Present address: Dept. of Horticulture, Texas Technological College, Lubbock, Texas.

good responses to all morphological variations noted. Other varieties used to a certain extent in duplicated experiments were North Star and Ioana.

MEASURING PLANT RESPONSES

Numerous plant responses have been reported for evaluating the effect of 2,4–D sprays on corn. These include yield, plant height, dry weight, brace root proliferation, leaf rolling, stem bending, stem brittleness, and physiological maturity as measured by tassel, silk, and kernel maturity.

It is confusing to a worker who anticipates the use of one or several of these criteria of effect of 2,4–D to know which ones to choose, since critical evaluations of them are not to be found in the literature. A common error of workers in the past has been failure to distinguish clearly the type of response used by referring to them merely as "foliage" responses or "plant responses". This disregards the wide differences in sensitivity between responses to 2,4–D applications and, coupled with lack of appreciation of the natural differences in degree of expression of a response by different varieties, has led to erroneous conclusions by the worker and incorrect interpretations of results by the reader.

From general observations and the data of numerous experiments a limited evaluation of the more useful plant responses is presented.

1. *YIELD:* From the practical standpoint, yield is the most valuable response but its use must be confined to field experiments. It was least sensitive of all the measurements and was generally moderately variable within a series of an experiment. Differences in yield between two series usually would not show statistical significance unless gross differences in plant morphology existed between the two series.

2. *DRY WEIGHT:* Dry weight was the least sensitive of the greenhouse measurements and was moderately variable (co-efficient of variability = 15 to 30 per cent). However, it was consistent from experiment to experiment.

3. *BRACE ROOT PROLIFERATION:* Of the responses which are most sensitive to 2,4–D applications, brace root proliferation was found to be least variable within a series and was the most consistent between experiments. Ratings were easily and quickly made.

There are certain limitations however on the use of brace root responses. First, the degree of brace root response is proportional to plant vigor. Also, Zink (1949) and Murray and Whiting (1949) observed marked differences in degree of response obtained between different varieties. This necessarily restricts use to comparisons within a variety, unless similarity of response between varieties is established by previous test. A third limitation is age of plant at time of treating. Murray and Whiting (1949) concluded that the permanent root system of corn was highly susceptible to 2,4–D injury when foliar sprays were applied to the first-to-fifth leaves in early stages of growth but that older plants are less susceptible to this injury. From data obtained by the author it was clearly evident that spray

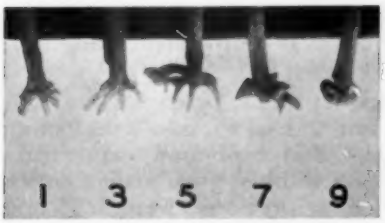

FIG. 1. Rating scale used for measurements of brace root proliferation.

FIG. 2. Varietal difference in leaf rolling response to 2,4–D foliage sprays: Carmelcross (left) and Ioana (right).

applications made at the 12″ stage resulted in proliferation responses out of proportion to the ultimate effect of the spray upon the plant.

The rating system for brace root response used in both field and greenhouse work is illustrated in Fig. 1.

4. *LEAF ROLLING:* Expression of this response varied greatly between varieties. In contrast to Carmelcross, Ioana did not give a measurable response, Fig. 2. The method of measuring leaf rolling which proved to be the best was enumerating the number of leaves showing permanent roll after the inner leaves had emerged.

5. *STEM BENDING:* This response has had considerable use in field work, but for greenhouse studies should be confined to seedling plants or to only those occasions when other responses are not applicable. It proved highly variable within a treatment, i.e. co-efficient of variability of untransformed data occasionally exceeded 100 per cent.

6. *TASSEL MATURITY:* As an indication of physiological maturity, tassel development was more sensitive than dry weight but less sensitive than other plant responses. It was consistent and of low variability. In the present series of experiments the following rating system proved to be satisfactory:

0 = Tassel not emerged
3 = Tassel emerged but rachesis not separated
6 = Rachesis 50 per cent separated but no pollen dehisced
9 = Pollen dehisced

SUMMARY

To permit more accurate conclusions, two or more of the responses described above were used to evaluate the results of a given test.

EFFECT OF TEMPERATURE

LITERATURE

Using quantitative methods of measuring the unabsorbed spray residue remaining on the foliage at the end of a 4-hour period after

application of 2,4–D, Rice (1948) concluded that the rate of absorption in kidney bean plants was greater at temperature ranges of 86–92° F. than at ranges of 46–58° F.

Kelly (1949) exposed plants of kidney bean, perennial rye, and crabgrass to temperatures of 5, 15, and 25° C. for one week before spraying. When sprayed and then placed at a common temperature (15° C.), plants previously kept at 25° exhibited greater stem curvature, leaf roll and swelling than did those previously kept at 15 and 5° C. She concluded that the higher temperatures affected the sensitivity of the cells directly.

Weintraub and Brown (1950) studied the influence of temperature upon changes in degree of response after the response was committed and its degree was known. Kidney bean seedlings were sprayed with 2,4–D and the degree of repression of opening of the first trifoliate leaves was noted. They then exposed the repressed seedlings to temperatures ranging from 22 to 34° C. From the results obtained, they concluded that repression of this growth expression was not a temperature-limited process.

Work by Staniforth and Bryan (1950) indicated that absorption of 2,4–D by leaves is not a simple case of diffusion. When plants were exposed to temperatures of 5 to 25° C. after treating and before washing to remove 2,4–D residues, plant response was approximately doubled by a 10° C. rise in temperature. They suggest that some type of chemical or enzymatic reaction was limiting absorption.

There are numerous reports in the literature Willard (no date), Denward & Aberg (1947), Hamner & Tukey (1944), Marth & Davis (1944–45), and others of work in which temperature was found to influence the time required for the expression of a response, usually death, of the plants to 2,4–D. Such reports demonstrate primarily the effect of temperature on the rate of physiological activity or morphological development, which in turn influences the rate at which the response is expressed by the plants.

PROCEDURE AND RESULTS

The effective factors, rate of absorption and cell sensitivity (Rice, 1948 and Kelly, 1949), were studied by use of both a prolonged and a short temperature exposure period which preceded and continued after the spray application had been made.

In the long exposure study, two separate experiments were conducted. Plants of both experiments were grown in the greenhouse. Both involved exposure in control chambers to a low temperature of 60° F. and a high of 90° F. for a period of 3 days prior to and 5 days following spray application. Relative humidity in both experiments averaged approximately 80 ± 5% at the 60° temperature and 70 ± 10% at the 90° temperature. Growth prior to and following the treatment period was in the greenhouse where temperatures averaged 60–80° F. and 60–85° F. during the first and second experiments, respectively.

Exposure of sprayed plants to the 90° F. temperature resulted in

a distinctly greater brace root proliferation response over that produced at the 60° temperature (Table 1). Leaf rolling gave a slightly greater response at the higher temperature and the dry weight decrease showed a similar trend.

The short exposure experiment involved exposure to 60° and 90° F. temperatures in control chambers for 3 hours prior to and 1 hour following foliage sprays. In order to lengthen the period of exposure of 2,4–D on the foliage and thereby obtain responses intense enough to measure, all plants were moved to a common temperature of 75° F. after the 1-hour post-spray period and spray was permitted to remain on the foliage for an additional 5 hours, after which time the leaves were washed.

Trends in response from the 4-hour exposure treatment (plus 5 hours at 75°) were identical to those obtained with long exposure at each temperature, except that responses under the short exposure were somewhat more extreme (Table 1).

Table 1. Effect of high and low temperature upon the response of sweet corn to spray applications of 2,4–D.[1]

Temperature	Brace root proliferation (rated 1–9)		Number rolled leaves		Dry weight (ounces)	
	Long exposure	Short exposure	Long exposure	Short exposure	Long exposure	Short exposure
60°	3.2	2.5	2.7	2.8	10.84	—
90°	5.2	6.8	3.0	3.7	9.88	—

[1]Data are averages of 20 and 40 plants for the short and long exposures respectively.

Exposure to a temperature of 90° F. resulted in greater responses to 2,4–D sprays than resulted from exposure to 60° F., whether the period of exposure was for 8 days or for 4 hours. The data do not permit conclusions as to whether or not rate of absorption is the principal effect temperature exerts on plant response to 2,4–D.

EFFECT OF LIGHT INTENSITY

LITERATURE

Working with red kidney bean, Mitchell and Brown (1946), Weaver and DeRose (1946), Rice (1948), and Davis (1949) observed that plants grown under conditions of reduced light intensity gave reduced responses to foliage applications of 2,4–D. Rohrbaugh and Rice (1948, 1949) obtained no response from 2,4–D when applications were made to leaves of bean plants which previously had been depleted of reserve carbohydrates by exposure to total darkness. Mitchell and Brown (1946) and Weaver and DeRose (1946) obtained positive correlations of degree of response of plants to 2,4–D with sugar content of treated leaves. Rice (1948) added sucrose to the 2,4–D spray solution and obtained increased plant responses. Davis (1949) and Rohrbaugh and Rice (1948, 1949) increased the carbohydrate content of plants exposed to total darkness by immersing

leaves in a sugar solution, and were successful in obtaining responses from 2,4–D. All workers concluded that failure of plants to respond to foliage treatments of 2,4–D under conditions of low light intensities, or the absence of light, was associated with low carbohydrate content.

Should a similar physiological relationship between carbohydrates and effect of 2,4–D on the plant exist in sweet corn, one can speculate that such prevalent modifications of light intensity as shade and dense overcast might influence ultimate responses to 2,4–D.

PROCEDURE AND RESULTS

To determine whether a response obtained from exposure of plants to reduced light intensities was due to a physiological condition induced during a period of low light prior to the 2,4–D application or a period following it, the experiment was executed in two series: (1) exposure to reduced light preceding spray application, and (2) exposure to reduced light following spray application. Carmelcross variety was used in both series.

Except where noted, plants were grown at 60–80° F. The treatment period of the experiment was carried on in control chambers where uniform conditions of temperature (90° F.), relative humidity (60%) and photoperiod (14 hrs.) were maintained. "Full" and "low" light intensities of 1100 and 150 f.c. were used. In both series plants were in the control chambers 2 days before and 2 days after spraying.

It became necessary to hold plants of Series No. 1 at 45–60° F. for 4 days prior to placing them in the control chambers. During this period sunlight intensity was high. Probably this contributed to an accumulation of a high carbohydrate reserve by the time plants went into the control chambers.

In Series No. 1 the 2-day low-light treatment preceded the 2,4–D application and continued for an additional 12 hours. The leaves were then washed and full light was restored. Plants remained in full light at 90° for an additional 36 hours before being returned to the 60–80° greenhouse.

Series 2 was similar to Series 1 except that for the 2-day period prior to spraying all plants were maintained at full light in control chambers. Immediately following spraying, the light intensity over part of the plants was reduced to the low level. After 12 hours, spray residues were washed from the plants. All plants were taken to the greenhouse 36 hours later.

Plant responses to 2,4–D from the low-light treatment (Table 2) were consistently less than those from the full-light treatment. It can be seen in Fig. 3 that differences in brace root proliferation were much wider in Series 2 than in Series 1. Considering all differences, however, it is probable that low light and low carbohydrate supply do not condition the response of corn to 2,4–D to as great an extent as they condition the response of bean.

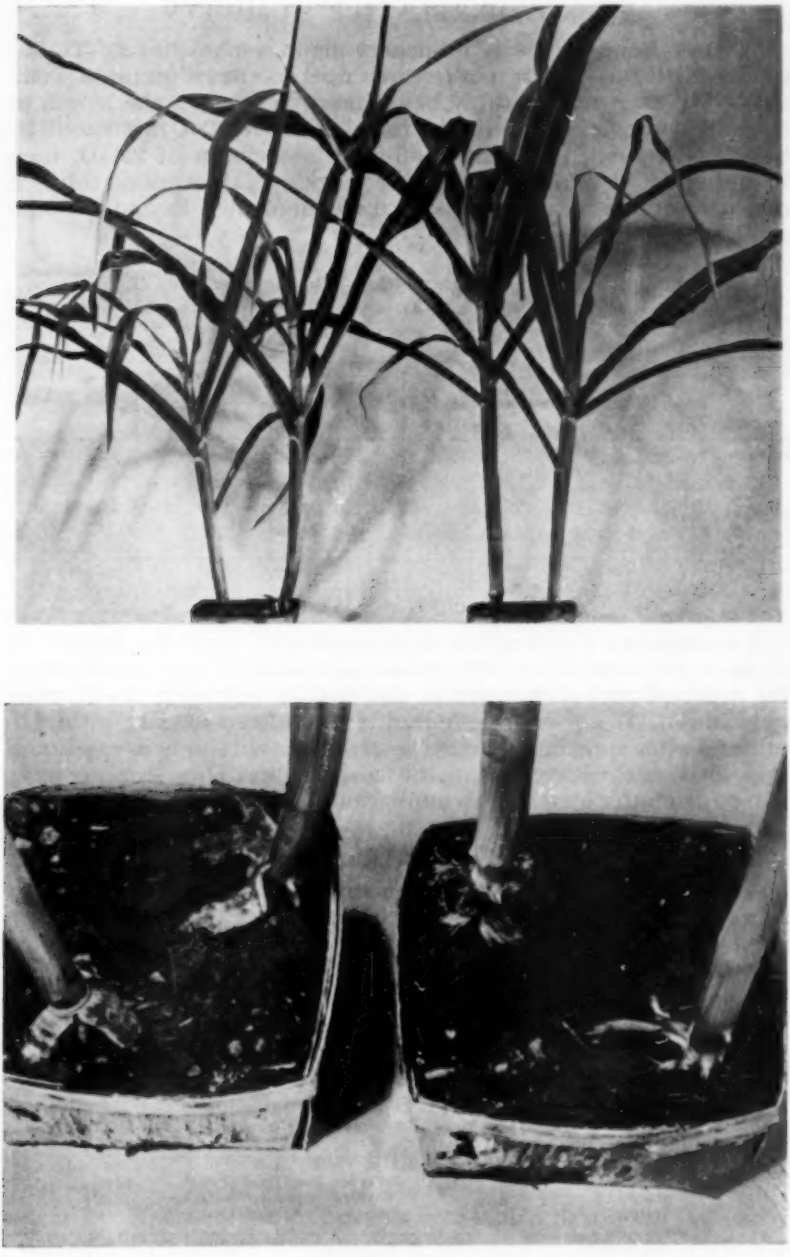

FIG. 3. Effect of exposure to high and low light intensities for 2 days following spray application of 2,4–D. Low-light plants (right) have slightly less leaf rolling and brace root response from 2,4–D than do those exposed to high light.

EFFECT OF RELATIVE HUMIDITY

Relative humidity, as it influences plant response to 2,4–D, has received little attention from research workers. Based on three premises, however, it may possibly be of importance: first, the length of time sprays remain in a liquid form on the leaf is influenced by humidity; second, if stomates influence absorption of 2,4–D, then humidity could indirectly retard or accelerate absorption; third, if cuticular development influences absorption, then humidity could indirectly affect absorption.

Table 2. Effect of exposure to high and low light intensity upon the response of sweet corn to spray applications of 2,4–D.
(Data represent averages of 20 plants)

Period of low light intensity	Brace root proliferation (rated 1–9)	Number rolled leaves	Dry weight (grams)
Preceding Spray:			
1100 F.C.	5.0	3.2	8.91
150 F.C.	3.8	3.1	9.09
Following Spray:			
1100 F.C.	6.2	3.3	9.24
150 F.C.	3.1	3.1	10.73

PROCEDURE AND RESULTS

Two separate experiments were conducted. In both, humidities of 40 ± 10% and 90 ± 10% were maintained in control chambers for a period of 3 days prior to and 5 days following 2,4–D spray application. At low relative humidity the foliage was dry within 15 minutes after spraying, whereas at high humidity some spray liquid remained on the leaves for more than an hour. There was no spray run-off from the leaves or accumulation in the "throat" of plants.

Data of Experiment No. 1 indicate a trend of greater plant response at low than at high relative humidity (Table 3).

In Experiment No. 2, at low relative humidity, brace root proliferation and leaf rolling show a greater effect than that noted in Experiment No. 1. Tassel maturity was retarded at the low humidity, and average dry weight was less than at the high humidity (Table 3). These findings corroborated the trend noted in Experiment No. 1.

Table 3. Effect of high and low humidity upon the response of sweet corn to spray applications of 2,4–D.
(Data represent averages of 20 plants)

	Brace root proliferation (rated 1–9)		Number rolled leaves		Stem bending (degrees from vertical)		Tassel maturity (rated 0–9)		Dry weight (grams)	
	Experiment		Experiment		Experiment		Experiment		Experiment	
	1	2	1	2	1	2	1	2	1	2
Low	6.2	6.3	—	3.2	17.5	—	—	2.2	4.97	13.08
High	4.7	2.4	—	1.6	14.5	—	—	6.2	4.76	16.40

The basic hypothesis of the experiment proved to be incorrect. Low, rather than high relative humidity, gave responses which, in brace root proliferation, leaf rolling, and tassel maturity, were all significantly greater in intensity. No explanation is offered to account for the results obtained.

EFFECT OF RAINFALL

LITERATURE

That rainfall may influence the response of plants to foliage applications of 2,4–D was established by Weaver, Minarik, and Boyd (1946). Working with soybean, they obtained progressive reductions in yields as the time interval between spray application of artificial rainfall increased from 1 to 6 hours, 6 to 24 hours, and 24 hours to "no rain".

Slife and Fuelleman (1949) reported stunting and malformation of corn plants when pre-emergence applications of 2,4–D at three pounds per acre were followed by heavy rains. The general observations of Dearborn, Sweet, and Havis (1948) and Van Geluwe and Tafuro (1949), although less pronounced, concur with these findings.

Although the work of these investigators demonstrates that rainfall may influence the various responses of plants through effect upon foliage and soil residues, it is impossible to separate and evaluate the potential contribution of foliage and soil residues in the production of the varied responses noted following rain. To obtain information on this, two separate experiments were designed: (1) A study of the effect of length of contact period of sprays on foliage, independent of soil effect; and (2) A study of the effect of rainfall on soil applications at various stages of growth of the plant, independent of foliage effect.

PROCEDURE AND RESULTS

Foliage Effect: Twenty plants per treatment were used, with containers arranged in systematic design. Four treatments were given: (1) spray followed by rain after 1 hour, (2) spray followed by rain after 6 hours, (3) spray but no rain treatment, and (4) unsprayed control. Artificial rainfall was applied with a fine spray hose nozzle with the flow timed to deliver approximately one acre-inch of water in about ½ hour. Precaution was taken to prevent the leachate from coming into contact with the soil. The plants in the experiment were sub-irrigated. Plants were harvested after tassel emergence (53 days).

Results are presented in Table 4. In all responses, a progressive increase in effect was obtained with increase in time of exposure of 2,4–D on the foliage (Fig. 4). In contact with foliage for one hour, a definite response from the spray was obtained. It did not, however, produce differences which in all cases were significant from the controls. Lengthening the time of exposure to 6 hours greatly increased the intensity of all responses, which were significantly greater than the one-hour series in all comparisons.

Table 4. Effect of length of time of exposure of 2,4–D on foliage upon plant responses in sweet corn.
(Data represent averages of 20 plants)

	Brace root proliferation (rated 1–9)	Number of rolled leaves	Tassel maturity (rated 0–9)	Dry weight (grams)
Control	0.0	0.0	4.8	15.72
1 hour	1.1	0.5	4.0	15.57
6 hours	5.3	2.5	1.0	13.65
No rain	7.3	3.4	0.7	11.67

[1]Differences between the two treatments indicated was not significant at odds of 19:1. All other possible comparisons within a response were significant at odds of 19:1 or greater.

FIG. 4. Effect of artificial rainfall upon the response of sweet corn foliage applications of 2,4–D. Plants represent typical leaf rolling and brace root response of (left to right) the "No rain", 6 hour exposure, 1 hour exposure treatments and the control.

Soil Effect: The general design of the experiment was the same as that used in the foliage effect study. Four series were used in the experiment: (1) pre-emergence, (2) post-emergence at two inches, (3) post-emergence at ten inches, and (4) unsprayed control. In order to eliminate a possible interaction of treatment with effect of environmental conditions at the time of each spraying, plants were grown to a height of one foot under controlled conditions; temperature 79 ± 2° F. day and 71 ± 1° F. night; light intensity, 900 f.c. and rela-

tive humidity 60 ± 5%. As a precaution against spray contact with aerial parts in the post-emergence treatments, bases of plants were wrapped with one-quarter-inch cotton batting.

To obtain maximum effect of spray residues without encountering leaching from containers, surface irrigation, using approximately one-fourth acre-inch of water, was applied twice daily for a period of 3 days following the spray applications.

The effect of surface water applications following application of 2,4–D to the soil gave greatest response as measured by stem-bending in the pre-emergence series and least response in the ten-inch series (Table 5).

Table 5. Effect of 2,4–D soil sprays followed by surface water applications on plant responses in sweet corn.
(Data represent averages of 20 plants)

	Stem bending 4–6 days after treatment (degrees)	Tassel maturity (rated 0–9)	Dry weight (grams)
Control	1.0	6.0	21.71
Pre-emergence	11.3**	5.3	18.00*
Post-emergence at 2 inches	6.5**	6.0	19.60
Post-emergence at 10 inches	1.0	4.8	20.26

*Difference from control significant at odds of 19:1; **significant at 99:1

The marked response of plants in the pre-emergence series was further borne out by the development of fasciated brace root bands on one-half of the plants of the series within 15 days after treatment. The two-inch soil spray series failed to show brace root stimulation and, although some brace root stimulation was noted in the 10-inch soil spray series, no plant exhibited fasciation and the total stimulation represented only five percent of that exhibited by plants of the comparable foliage spray series.

Discussion and Conclusions

Results of these experiments indicate that a 1-inch rainfall occurring within 1 hour after application of 2,4–D to foliage of 10-inch sweet corn plants will eliminate most of the effect of the spray. This reduction in plant responses is a foliage effect. If rainfall is delayed for 6 hours, 2,4–D sprays will cause plant responses of an intensity approaching continuous contact. The lessening of effects from foliage sprays by early rainfall will be partially counteracted if the spray residue is leached into the root zone.

The data show that the effect of soil residues on seedling plants may be great and may significantly reduce the total subsequent development of the plant. Intensity of response is decreased as the size of the plant increases to 10 inches.

Although significant differences in morphological development occurred when residues were carried into the root zone of plants at various stages of development, maturity was not significantly affected. In contrast, maturity of plants receiving foliage sprays was delayed significantly when an interval of 6 hours elapsed between the time of spraying and the 1-inch rainfall.

EFFECT OF STAGE OF MATURITY

LITERATURE

As noted earlier, the use of 2,4–D sprays for weed control in corn has frequently caused concern because of marked foliage responses. This has led to the focusing of considerable emphasis upon studies of rate of application and stage of maturity of the crop plants at the time of application. Studies of rate have been numerous and, although somewhat variable, have resulted in conclusions which, within limits, are now considered to be reasonably satisfactory. Less numerous and much less specific are the results of studies of stage of maturity.

All of the early reports of studies of stage of maturity at the time of spray application concluded or implied minimum effect to plants when 2,4–D was applied at 10–12 inches. Later papers, Buchholtz (1948), Lee (1948), Viehmeyer (1948), Lee (1949), Slife and Fuelleman (1949), Fertig (1950) and Willard (no date), did not support the earlier conclusions.

From the apparent weight of evidence, one might conclude that 2,4–D response in corn was greatest when plant height at the time of treatment was greater than eight inches, and that for least effect, post-emergence sprays should be applied at 2–5 inches. No single report, however, can be considered to represent accurate comparisons of effect of 2,4–D applied at the various stages of growth. There are several reasons for this:

(1) No experiment was designed to eliminate the effect of difference in environmental factors and vigor of plant growth at the time spray was applied.

(2) Results of most experiments are based on differences in stem bending, brace root and foliage responses which, with the exception of stem bending, increase in rateable magnitude as the respective plant part increases in age.

(3) Varietal differences in degree and mode of expression of foliage responses were not always considered where more than one variety was used.

It was with intent to determine the influence of stage of growth upon the effect of 2,4–D in corn plants, independent of other variables, that this study was undertaken.

PROCEDURE AND RESULTS OF GREENHOUSE EXPERIMENTS

Four series of 20 plants each, arranged in a systematic design, were used in the experiment. (For details of procedure see first two paragraphs "Rainfall," soil effects section, page 150.)

To permit inter-comparisons of initial responses, early measurements on the pre-emergence and the two-inch treatments were made of stem bending and plant height. The probable influence of physiological and morphological differences between plants at the time of treatment exclude the possibility of comparing responses of the ten-inch treatment with those of the remaining series of the experiment. For inter-comparisons among all series, only the tassel emergence and dry weight data were considered usable.

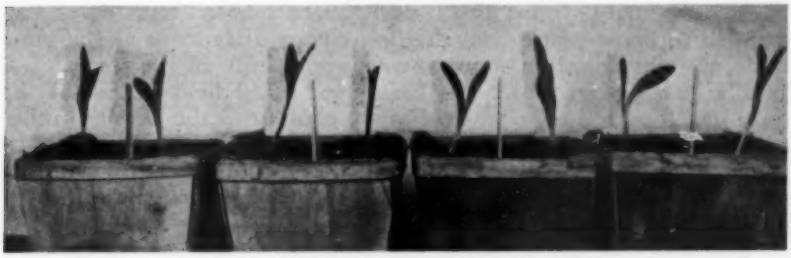

FIG. 5. Effect of stage of plant development on response of sweet corn to 2,4–D. Left to right – Control, Pre-emergence, 2″ Soil, and 2″ Foliage Spray Series. Note stem bending and elongation of lower internode of Pre-emergence and 2″ Foliage series, and the marked leaf rolling of the Pre-emergence series. A band of fasciated brace roots is visible approximately ½″ above the soil on the left plant of the Pre-emergence series.

Measurements of stem bending indicate that 2,4–D sprays had a marked effect in both the pre-emergence and the two-inch foliage spray series (Fig. 5). The response of the two-inch soil spray series was significantly less than that of the foliage spray series (Table 6). The trend in height appears to corroborate that noted in the bending response.

Data taken at the termination of the experiment (Table 6) show that of the five treatment periods, greatest ultimate effect of the 2,4–D spray was from the ten inch foliage application. Delay in tassel emergence and reduction in dry weight were both highly significant. The lasting effect of the spray in the pre-emergence series was evident in the significant but moderate decrease in dry weight. The two inch soil and foliage as well as the ten inch soil spray series ultimately showed no differences from the control.

Table 6. Influence of plant maturity at time of spraying on corn response to 2,4–D. Data are averages of 20 plants.

Treatment	Initial response			Final responses			
	Stem bending[1] (degrees)	Plant height (inches)	Leaf rolling (per cent)	Tassel emergence (0–9)	Brace root proliferation (1–9)	Dry weight (grams)	Leaf rolling (number)
Control	1.0	3.00	0	6.0	—	21.7	0.0
Pre-emergence	11.3*	2.83	40	5.2	—	18.0*	0.0
2 inch soil	6.5*	2.95	0	6.0	—	19.6	0.0
2 inch foliage	11.0*	2.90	55	5.6	—	20.5	0.0
10 inch soil	—	—	30	4.8	0.2	20.3	0.7
10 inch foliage	—	—	100	0.7**	7.0	13.0**	3.6**

[1]Data represent maximum measurements during 1 week after spraying.
*Significantly different from control at odds of 19:1 or greater.
**Significantly different from control at odds of 99:1 or greater.

PROCEDURE AND RESULTS OF FIELD EXPERIMENTS

There are two general ways in which studies involving measurements of the effect of stage of maturity of plants at the time of 2,4–D application can be designed: (1) All plots can be planted simultaneously and then sprayed on different dates as the plants grow to the

desired maturity groups, or (2) seed can be planted at intervals calculated to bring plants into the desired maturity stage at the same time, thereby enabling simultaneous application of the spray.

The first design, which has been used in all field studies of the problem reported to date, necessarily confounds the possible influence of differences in environmental conditions on the intensity of effect of the spray on the plants. Adequate replication by planting date or by years may be expected to reduce but not eliminate the effect of this error.

Theoretically, the second design eliminates the factor of environment from comparisons and gives a valid picture of the stage of maturity x 2,4–D treatment interaction.

By use of the second design, summarized in Table 7, field experiments were undertaken with intent to determine the influence of stage of maturity upon response of sweet corn to 2,4–D. They were conducted on a Chenango silt loam soil, Ithaca, N. Y. in 1949 and 1950. The experimental design, which was identical for the 2 years, was a split-split-plot using 3 varieties randomized in each of 3 stages of plant growth at the time of spraying, and 5 dates of planting with 3 randomized replications in each date.

North Star, Carmelcross, and Ioana varieties were selected because they represented 3 maturity groups and at the start of this work were considered to represent, respectively, maximum, median, and minimum response to 2,4–D.

Rows were 16 feet long, and 4 seeds were planted per hill with hills 1 foot apart. Plants were thinned to 2 per hill when they were 3 to 4 inches tall. Check rows were used between adjoining maturity blocks and the first plant at the end of each row served as a check.

Amine salt of 2,4–D sprays at 1 pound per acre in 100 gallons of water were applied with a 3-gallon portable spray using a fan type nozzle (Teejet #8002). Spray was applied vertically from a height of 18 inches above the soil when plants were dry and air was calm.

As a means of eliminating the factor of weed competition from unsprayed plots and from plots sprayed later, all weed growth was removed by surface hand cultivation.

Harvesting was done when the majority of the ears fell into the marketable stage. Only marketable ears were used for record. Weight was recorded in ounces of green corn per 15 feet of row.

In general, the climate during the 1949 growing season was dry and hot and resulted in reduced yields in Replicates I, II, and III. In 1950 the month of June was cold and wet and the temperature during July was below average. Replicate I, and Ioana in particular, was retarded.

Analysis of combined data resulted in a highly significant difference in performance of plants on different planting dates. A comparison of treatments between dates, as illustrated in Table 7, was therefore not valid unless the data were related to the performance of the particular date involved. In order to make this correction, all data were related by covariance (Snedecor, 1946), to the performance of control plants grown in the same replicate of the same planting

date as the treated plants. Tests of significance of comparisons were accomplished by covariance analysis.

Limitation of comparisons to those sprayed on the same date, (Table 7), makes possible only three comparisons of yield responses of pre-emergence with two-inch stage, two comparisons of two-inch with one foot stages, and one simultaneous comparison of all three stages.

Comparisons of pre-emergence with two inches showed a highly significant reduction in yield of the latter (Table 8).

Table 7. Date of spraying each stage of maturity treatment of each date of planting.

Date of spraying	Dates of planting (1949)				
	June 7	June 15	June 23	June 30	July 8
June 7	Pre-emergence	———	———	———	———
June 15	2 inch stage	Pre-emergence	———	———	———
June 23	———	2 inch stage	Pre-emergence	———	———
June 30	12 inch stage	———	2 inch stage	Pre-emergence	———
July 8	———	12 inch stage	———	2 inch stage	Pre-emergence
July 15	———	———	12 inch stage	———	2 inch stage
July 23	———	———	———	12 inch stage	———
July 31	———	———	———	———	12 inch stage

Table 8. Influence of stage of maturity at time of 2,4–D spraying on yields of sweet corn in ounces per plot.
(Data corrected to control by covariance)

	3 comparisons	2 comparisons	1 comparison
Pre-emergence	601**	——	676**
2 inches	522	567**	519
12 inches	——	517	531

**Difference significant at odds of 99:1.

There was a highly significant reduction in yield of the 12-inch treatment below that of the two-inch treatment. In the single comparison of the three stages sprayed on the same date, the trend between pre-emergence and two-inch stages was similar to that already noted. However, there was no difference between the 2 and 12-inch stage.

DISCUSSION

The data of the field experiment established a definite trend of increased injury with increased plant age at time of spraying.

With one exception, this trend corroborated the data of the greenhouse experiments. The major discrepancy between the two experiments is the marked injury obtained from greenhouse pre-emergence sprays, whereas none was obtained from field pre-emergence. This discrepancy may be readily accounted for when one considers the conditions under which each experiment was conducted. In the greenhouse, 2,4–D soil residues were intentionally leached into a shallow root zone in an attempt to obtain the maximum effect of the spray. In the field, a dry surface prevented root growth in the top inch of soil and infrequent rains did not carry 2,4–D residues into

the root zone. The two experiments, therefore, illustrate the maximum and the average effects respectively of 2,4–D applied as a preemergence spray.

EFFECT OF 2,4–D ON TRANSPIRATION RATE

LITERATURE

It has often been speculated that 2,4–D applications might affect water relations of plants indirectly by altering their transpiration rates and thereby affect ultimate growth and yield. Working with bean seedlings, Bradbury and Ennis (1949) observed that a higher percentage of stomata were closed or partially closed in treated than in untreated plants. They observed further that water loss from plants treated either through the roots or foliage was less than check plants.

Player (1950), working with low-concentration sprays (100 ppm) with corn, concluded that average total transpiration of treated plants was not affected by treatment with 2,4–D spray.

The spray concentration used by Player, however, was considerably below the range normally recommended for field application to sweet corn.

PROCEDURE AND RESULTS

It was considered desirable, in the present experiments, to approach the problem using maximum concentrations normally used as foliage sprays to learn whether alteration in transpiration rate would result under conditions optimum for foliage response.

Preliminary measurements of 30-inch plants with central leaves still tightly coiled (Fig. 4) indicated that under these conditions average transpiration of the entire plants was reduced from 15 to 20 per cent below controls, although size of plants, as indicated by dry weight, was unchanged. These results, however, could have been brought about simply by the smaller surface exposed in the case of the treated plants.

Plants were suspended in an aerated solution culture contained in 1-liter flasks. Hoagland's #1 solution was used and changed each week. Ferric tartrate was added every 2 to 4 days as was required. To provide shade for the roots, flasks were placed in covered #10 cans. Spraying was delayed until the plants had attained an average height of 15 inches in order that minor changes in transpiration rate could be readily measured at low relative error. Spraying was done at 3:00 pm, and at a temperature of 85° F., relative humidity of 70% and light intensity of approximately 4000 foot candles. Relative transpiration losses were recorded volumetrically with estimated accuracy to 0.5 percent. Transpiration rates for individual plants were measured for a period of 2 days prior to the 2,4–D application, and the average for the two days was used as a basis of comparison of subsequent performance of each plant. Except for a 2-day period of low transpiration rate when a single measurement was made, post-treatment measurements were made daily. The experiment was concluded on the sixth day after spraying in order to avoid an inter-

action between treatment, per se and differences resulting from leaf rolling and other anatomical changes in treated plants.

Average daily loss per plant per day for the period of the experiment was 181.6 cc. There was no difference in transpiration rate between treated and control plants (Fig. 6). This is in agreement with the conclusion of Player (1950).

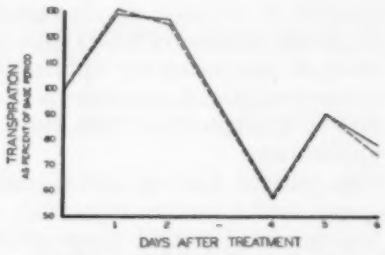

FIG. 6. Effect of 2,4–D on transpiration rate of corn. (Solid line represents control).

SUMMARY

A study was made of some of the factors which were considered to have a potential influence upon the variations in response of sweet corn to 2,4–D. The study was conducted under conditions of controlled environment in the greenhouse and one phase was conducted in the field. In all experiments, 1 pound per acre applications of 2,4–D (amine salt) spray were used. Plant responses measured to determine effect of 2,4–D sprays included brace root proliferation, leaf rolling, stem bending, plant height, tassel maturity, dry weight of plants, and yield.

Exposure of sweet corn plants to a temperature of 90° F. resulted in markedly greater responses to 2,4–D than were obtained at 60° F., whether the period of exposure to the temperature was for 8 days or 1 hour. The data were inconclusive as to whether rate of absorption alone was the factor influenced by temperature or whether sensitivity of cells to 2,4–D was also affected.

The effect of light intensities of 150 foot candles, for two-day periods either preceding or following spray application of 2,4–D, were found to be slight.

Rainfall was found to influence the response of sweet corn to 2,4–D sprays. When it occurred within 1 hour after spraying 8-inch plants, a 1-inch rainfall eliminated most of the effect of the spray. Remaining on the foliage for 6 hours, the spray affected plant responses to an intensity approaching that of continuous spray contact. The effect of soil spray residues when leached into the root zone of seedlings was very marked and significantly reduced the total subsequent development of the plants. Effect of the soil residues on older, emerged plants, was found to be slight.

The results regarding the influence of relative humidity upon plant responses were contrary to the general assumptions. Greater response to 2,4–D was obtained at low than at high relative humidity.

Results of field and greenhouse studies, in which 2,4–D applications were made at the pre-emergence, 2-inch, and 12-inch stages of maturity, indicated that response from the spray was greatest when made at the 12-inch stage, and least at the pre-emergence stage when plants were grown under field conditions. However, when conditions

were ideal for root development near the surface of the soil and when soil residues of 2,4–D were leached into the root zone, a marked effect of pre-emergence applications was obtained.

Spray applications made to 15-inch plants had no effect upon the rate of transpiration from the plants for a period of 6 days after application.

In general, findings of this study showed that when sweet corn was grown under conditions of high temperature or low relative humidity, or when sprayed at an advanced stage of maturity, a marked increase in the ultimate degree of response to 2,4–D was obtained. Also, as the time interval between spray application and occurrence of rainfall increased, the degree of response increased. In contrast, the influence of light intensity either before or after spraying on ultimate plant response was slight. Likewise, the effect of 2,4–D sprays on the rate of transpiration was negligible.

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The Design and Evaluation of a Small-Plot Sprayer[1] [4]

By S. K. Ries[2] and C. W. Terry[3]

The research worker who attempts the application of herbicides to a small area in such a way as to simulate general practice, is faced with a unique problem. The ultimate objective is to apply the chemical to as small an area as is feasible but in such a way that it will correctly represent what the activity on both weeds and crop plants would have been had the application been made on an acreage basis. Small plots are desirable if land or labor are limited, if expensive crops in farmers' fields are being used, and particularly when the chemicals may be highly toxic, or the activity is unknown.

An ideal small-plot sprayer would incorporate as many as possible of the following features:

1. Accurate herbicide applications should be easily attained on "small plots" of either a few or a few hundred square feet.
2. Cost should be low.
3. Construction and operation should be simple.
4. Operation should be accurate and efficient under a variety of soil conditions.
5. Changing from one herbicide to another should be rapid.
6. Contamination between herbicides must be negligible.
7. Agitation of spray liquid should be adequate for a wide range of materials and formulations.
8. Uniform pressure should be maintained.
9. Apparatus should be sufficiently light in weight to permit easy operation by one person without need of wheels, tractors, extra personnel, etc.

Several workers have developed small-plot sprayers for herbicidal work. Davis (1947) adapted a small pressure-grease-gun. One end was sealed and the plunger mechanism removed. Pressure was from an auxiliary air tank. Although adapted to small areas, agitation was not provided and quick changes were not easily made. Buchholtz (1950) developed an excellent sprayer for plots of thirty to forty square feet in area. Carbon dioxide was utilized for pressure. A small cylindrical tank attached directly to the boom and serving as a handle provided the reservoir for the solution. Unfortunately, however, to eliminate contamination, Buchholtz deemed it desirable to have separate tank and boom assemblies for different chemical solutions. Robinson and Dunham (1950) made a sprayer using pressure oil-cans for containers and compressed air for pressure. The cans were held in the hand and the large compressed air cylinder carried on the back. Agitation of the solution probably was provided by shaking the can. The sprayer described by Raleigh (1950) had many

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excellent features but provided no agitation and did not permit rapid changing from one treatment to another.

Shaw (1950) described an efficient sprayer mounted on bicycle wheels. The spray containers were converted knapsack sprayer tanks. This feature is an advantage where large plots or high volumes are being used, but for small plots one is often working with quantities of less than one quart. This makes for inefficient use of CO_2 or air pressure and unnecessary extra weight and bulk. Also, to permit rapid field work one needs to have considerable investment in extra knapsack tanks or extra field personnel for cleaning tanks and changing solutions.

In the 1951 Research Report of the North Central Weed Control Conference, ten different small-plot sprayers were described. Although each had several very desirable features, none met all the requirements listed above. The majority cost more than one hundred dollars. While this amount is not prohibitive, a lower cost outfit would help make equipment available to more individuals. Several of the sprayers were either tractor-mounted or tractor-drawn. For a few types of herbicide experiments extra space must be set aside at the end of the plot to permit the tractor to attain the proper speed before the apparatus enters the actual plot. Where large numbers of small plots are being treated this feature greatly enlarges the experimental area. Even though land may not be limiting, larger than necessary experimental areas are undesirable because of loss in the precision of the experiment, which can only be overcome by more replication.

Push-type sprayers mounted on bicycle wheels were also reported (N.C.W.C.C. 1951). Sprayers of this type however, are not suited to situations where the soil is rough, stony, or soft.

The objective of this work was to design a small-plot sprayer which would keep the desirable features of existing sprayers and in addition would: (1) be less expensive, (2) permit spraying plots almost any size up to about 500 square feet, (3) agitate the spray liquid.

It is recognized that nozzle design, size, wear, etc., greatly affect spraying results. Nozzle problems, however, are usually not peculiar to any particular sprayer, but are more likely to be associated with chemicals and formulations, precision of manufacture, etc. Nozzle variations, therefore, were considered to be outside the scope of this paper.

DESIGN OF A SMALL-PLOT SPRAYER

The equipment as finally designed is shown in Fig. 1. To facilitate presentation, the several components will be discussed separately.

Clamp top:

The clamp-top device was designed, by the junior author, to adapt obsolete milk bottles as a cheap, readily available container for chemicals. The clamp top is the "heart" of the spraying system. The design (Fig. 2) is patterned after the ordinary glass fruit jar snap closure, which allows for a quick change of bottles. For detailed

FIG. 1. Small-plot sprayer assembled as used.

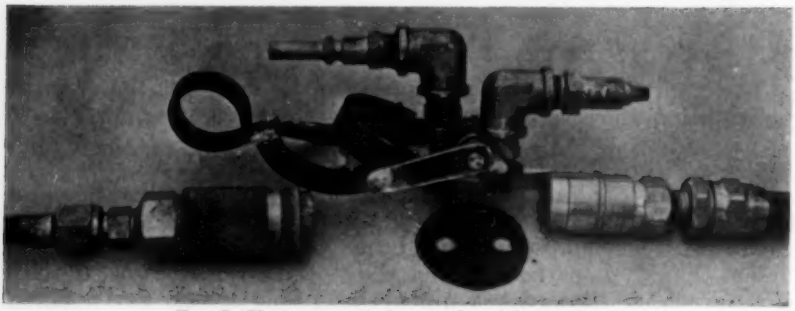

FIG. 2. Clamp-top, gasket, and quick-couplers.

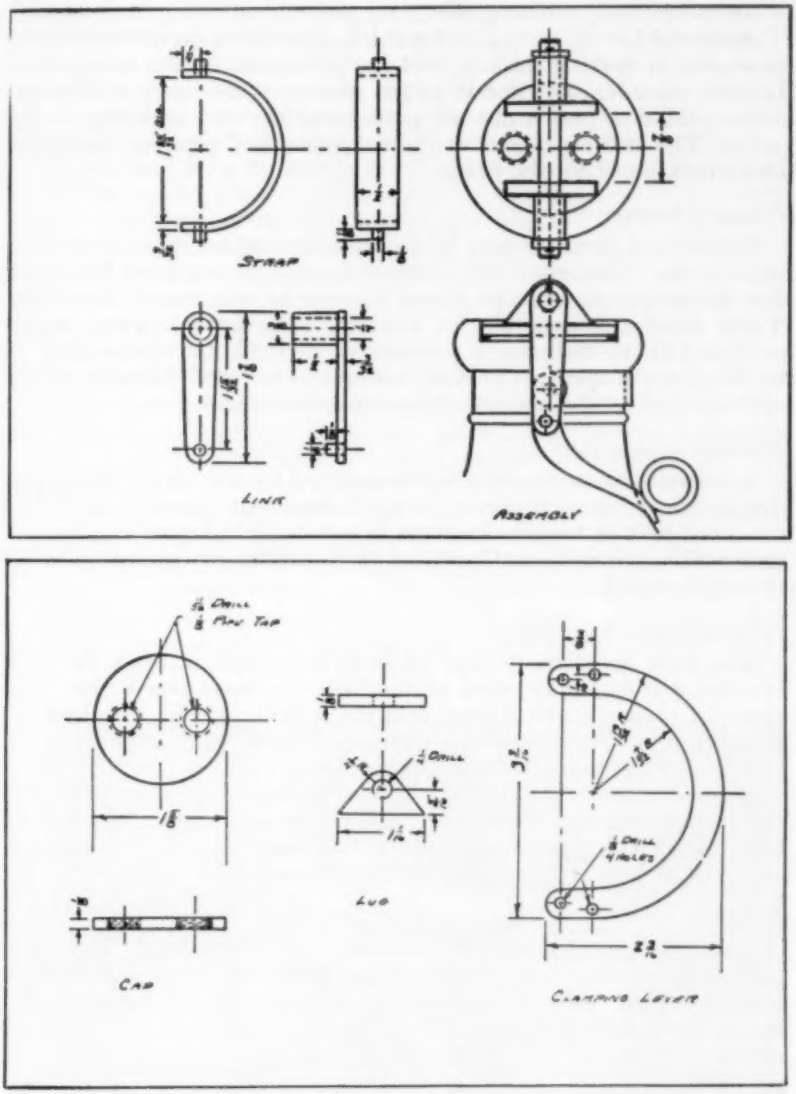

FIG. 3 (upper and lower). Working drawings for clamp-top. Dimensions are dependent on bottles used.

drawings of this design see figure 3. The dimensions given are for the bottles used in these experiments. Care should be taken to make appropriate changes if the lip and diameter of the bottle are not the same as shown in the figures.

Brass or galvanized iron fittings may be used for connecting the top to the pressure source and the spray boom.

An oil-resisting rubber gasket, such as is shown in Fig. 2, is needed. This should be $^1/_{32}$ to $^3/_{16}$ inches thick, depending on the variability produced in making the top, and the particular bottles being used. It saves considerable time if gasket cutters of the correct diameter are available to punch out the gasket and the two openings in the gasket. The authors used a sharpened galvanized pipe for the gasket and a cork borer for the holes.

Pressure Source:

A source of pressure may be from either carbon dioxide or compressed air. Ten-ounce CO_2 cylinders, such as are used for small fire extinguishers, were preferred because of the ease of handling. These small cylinders may be carried in the pocket. They supply enough CO_2 to maintain a pressure of 25 P.S.I. for discharging 30 to 40 bottles of spray. It proved economical to rent a large 50-pound cylinder and refill the smaller containers from this.

Pressure regulation:

A constant pressure may be maintained by use of an adjustable diaphram pressure regulator. A small regulator (fixed at 25 P.S.I.) was used by the authors because it was easily adapted to the ten-ounce CO_2 cylinder, and resulted in a satisfactory pressure for all materials tested.

Hose and quick couplers:

The most satisfactory type of hose for coupling both the CO_2 cylinder and the spray boom to the clamp-top was oxygen hose. This material proved to be lighter and more flexible than standard air pressure hose. Where oils are being used to an appreciable extent, an oil-resistant pressure hose is necessary.

Quick-couplers were used on both sides of the spray container to facilitate changing. When purchasing a quick-coupler, it must be ascertained that this coupler will not allow gas passage when pressures are as low as 25 pounds per square inch.

Valves:

Both spring-loaded and quarter-turn valves were tried. The quarter-turn brass valve was preferred due to its simplicity, and because it did not plug easily. If a spring-loaded valve is used, it is suggested that a small line strainer be placed between the valve and the milk bottle.

Boom:

The spray boom of a small plot sprayer is one of the most important factors in determining how effective the spraying job will be. Too often the boom construction is considered of little importance. When more than one nozzle is placed on a boom, that boom is adapted to spray only one width of plot, unless nozzle-angle and/or nozzle-placement on the boom is changed.

In designing a boom, the width of plot desired should be determined and a boom should be constructed to spray that exact width.

This is best done by plotting the theoretical angles of a nozzle so they cover the desired area, allowing the prescribed percentage of overlap for the nozzles used. It should be remembered that a nozzle is made to give a certain spray angle, but that it will only produce this angle through a very narrow pressure range. If different pressures are being used, adjustments for the angle must be made.

After determining the height the boom should be from the ground, a chain of appropriate length (Figure 1), was fastened to the boom to help the operator maintain the proper height.

The boom could be made lighter by using aluminum in place of the standard galvanized pipe, but this adds somewhat to the cost. Also, aluminum pipe was not readily obtainable and aluminum tubing proved too thin walled.

Bottles and protective screen:

When obsolete milk bottles are used, one treatment may be mixed, transported and sprayed from one bottle. Transparent containers enable the operator to see if the spray material is in the proper condition for satisfactory spraying. They also enable the operator to observe the liquid during the course of spraying. Regular milk bottle carriers (Figure 4) provide an efficient method of transport.

If cracked or checked, milk bottles will blow up even when subjected to relatively low pressure. This is exceedingly dangerous to the operator, and several precautions must be taken: (1) pre-test each bottle at the start of an experimental season under high pressures with appropriate safeguards. (Testing in a water system is quite safe).

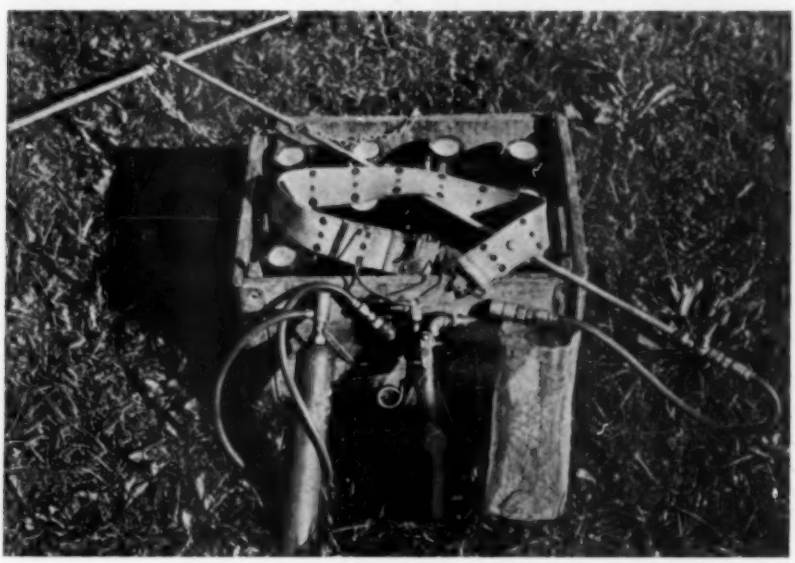

FIG. 4. One bottle case handles materials for twelve plots. Note protective screen on right and small CO_2 cylinder on left.

(2) Inspect each bottle for possible new breaks or checks before each plot is sprayed. (3) Before pressure is introduced, cover the bottle with a light mesh-screen. The screen must be in place during the entire spraying operation. Do not use a solid metal protective device such as a large tin can, because the expanding gas in case of a "blow" is confined and considerable damage may be done. The authors found ordinary galvanized window screening made an excellent protective device. By following the above precautions no bottles exploded during the course of applying chemicals to over 3000 plots.

Belt carrier:

A carrier to hold the milk bottle upside down was fashioned out of light wire and fastened to an army-surplus pistol belt as shown in Figure 5. The wire was designed so that it could be quickly unfastened to permit easy change of bottles. The inverted position gives excellent agitation of the spray liquid as the CO_2 enters the bottle.

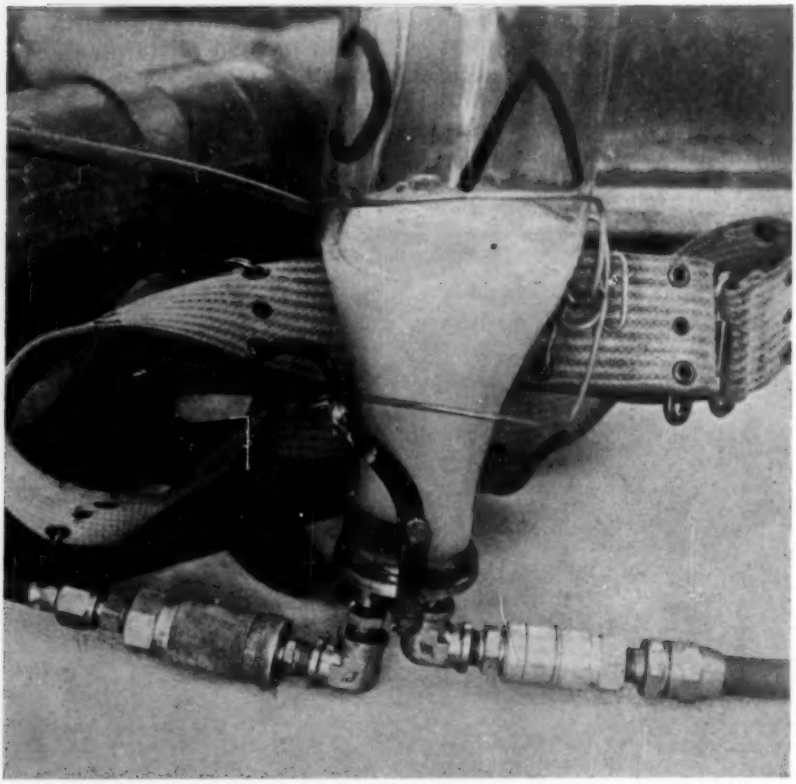

FIG. 5. Belt carrier and wire clamp for holding inverted bottle. Notice agitation resulting from CO_2 entering bottle.

Procedure for using sprayer:

The procedure for spraying is as follows: The boom is connected to the clamp-top with a quick coupler. The CO_2 cylinder and pressure regulator are placed in the operator's pocket with the pressure on. The clamp-top is placed on the bottle containing spray liquid. After the bottle has been placed in the screen, the quick coupler from the CO_2 bottle is attached. The bottle is inverted and placed in the belt carrier. The liquid should be inspected to determine if it is in condition for spraying. The system is now ready. For succeeding changes, disconnect coupler from CO_2 cylinder, remove the screen, remove the clamp-top and place on new bottle, replace screen and quick coupler, invert and fasten to belt, inspect the liquid and the system is ready to spray the next plots. Treatments were applied consistently at the rate of 60 plots (4′ x 15′) per hour.

EVALUATION

After obtaining a sprayer which seemed to be mechanically satisfactory, some of the following questions arose when trying to determine the accuracy and adaptability of the sprayer.

What is the best plot size? May more than one replication of a treatment be sprayed from one bottle without decreasing the accuracy of the test? Is it possible to apply the desired amount of liquid by merely changing the rate of walking or should one speed of walking be used throughout? Do growth regulators contaminate the spraying system so that other chemicals may not be sprayed without thoroughly cleansing the spray apparatus?

An effort was made to answer the preceding questions. Since there is no standard method or procedure in determining these factors developing a method proved to be difficult.

It must be stressed that the results given herein are those obtained from single experiments, and with the same operator at all times.

Plot size and plots per bottle:

The objective of these experiments was to determine the best plot-size for use with this sprayer, and, whether or not two or more replications could be sprayed from one bottle without significantly decreasing the accuracy of the application.

Rye was planted and the plots located before crop emergence. Two different experimental designs were utilized. In test 1, a 6 x 6 latin square was used. The plot sizes were 2 x 4, 2 x 12, 2 x 24, 4 x 4, 4 x 12, and 4 x 24 feet. Esso 45, a highly aromatic oil, was sprayed on the rye after emergence at the rate of 50 gallons per acre. This procedure involved the application of a different amount of liquid for each treatment. Three replications were sprayed from each bottle, with the exception of one treatment. Two replications were sprayed from each bottle on the 4 x 24 foot plot.

In test 2, a 4 x 4 modified latin square was utilized. The plot sizes were 4 x 4, 4 x 8, 4 x 16, and 4 x 32 feet. Only one-half of the total experimental area was systematically sprayed, which allowed a check

for each plot. Equal area was allotted to each treatment, regardless of plot size. The number of replications, however, varied according to treatment. The 32 foot plots had four replications, the 16 foot plots had eight replications, etc. DN (alkanolamine salts of 2,4–dinitro–ortho sec–butyl phenol) was sprayed on each treatment at a rate of eight pounds in 42 gallons per acre. This required a total of two quarts of spray per treatment.

A stop watch was used by a second person to obtain the spraying time for each plot. It was assumed that if all other conditions remained constant, the time it took to spray each plot would be a good estimate of how well each plot was covered with the spray. These tests will be discussed, therefore, on the basis of the time data obtained.

Two questions arose: 1) Was all of the spray applied to the assigned area? i.e., How much was left in the bottle after the plots were sprayed and what was lost to the spraying apparatus?, and 2) How uniform was the spraying operation? i.e., Was more spray applied to one plot than to another?

To answer the first question, the actual time it took to spray each plot was compared with the calculated time for spraying each plot. The calculated time was determined by measuring the amount of time required to spray four bottles of solution under the conditions of each experiment. The mean for each plot size was calculated from these data and compared with the actual mean for each plot. The results are presented graphically in Figure 6. It may readily be seen that the amount of liquid lost within each series of plots (two series in test 1, one series in test 2) was remarkably uniform. It is thought that this loss of liquid was due to the drip from the boom caused by a worn valve except for the 2 x 12 and 2 x 24 foot plots. In these cases, 40 and 60 c.c. of spray solution respectively was left in each

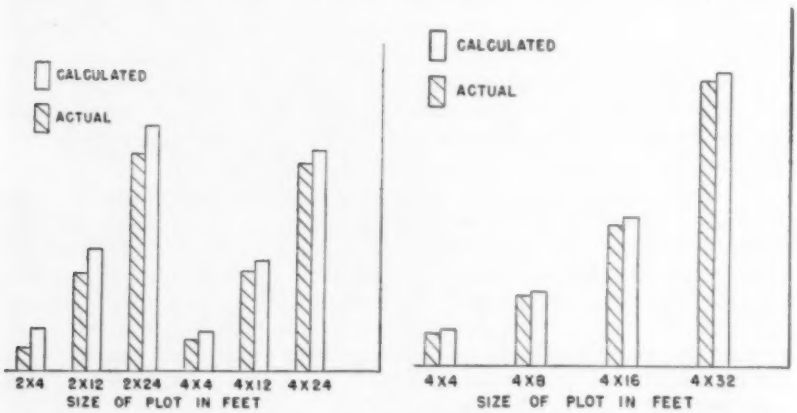

FIG. 6. A comparison of calculated and actual spraying times required in tests 1 and 2. Note that for each plot width, within a particular test, the error is remarkably uniform; consequently on a percentage basis error decreases proportionally as plot length increases.

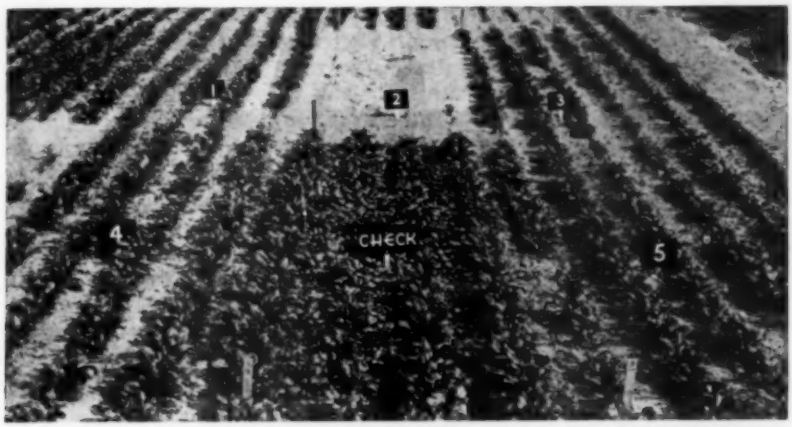

FIG. 7. Typical sharp demarcation between treatments obtained with the small-plot sprayer.

bottle after spraying was completed. It may also be concluded from Figure 7 that the desired amount of spray material was not applied to those plots which were only two feet wide and four feet long.

Figure 6 also points out the possibility of reducing the error due to loss from the spraying system by calculating an "Overage". From these data it would seem that this value would best be calculated by using a constant or absolute quantity rather than a percentage of the amount being sprayed.

If it is assumed that the desired amount of liquid was applied to each series of plots, the question of uniformity of application becomes pertinent. It was thought that this could best be answered by calculating the coefficient of variability for each plot size. These coefficients and other pertinent data are set forth in Table 1.

The coefficient of variability for all of the plots four feet long was high. This was probably due to the difficulty in starting and stopping the sprayer in only four feet. Also any error in time will affect the coefficient of variability more for the small plots because the mean is smaller.

Table 1. Effects of size and number of plots on the variability in time required for spraying.

Size of plot	No. of plots sprayed	No. of plots per bottle	Mean time for each plot (seconds)	Standard error of single observation	Coefficient of variability in per cent
Test 1					
2 ft. x 2 ft.	6	3	1.62	0.2291	14.14
2 ft. x 12 ft.	6	3	6.95	0.6083	8.75
2 ft. x 24 ft.	6	3	15.63	0.4583	2.93
4 ft. x 4 ft.	6	3	2.18	0.2933	13.45
4 ft. x 12 ft.	6	3	7.13	0.5604	7.86
4 ft. x 24 ft.	6	2	14.80	0.1673	1.13
Test 2					
4 ft. x 4 ft.	32	16	2.19	0.2590	11.83
4 ft. x 8 ft.	16	8	4.64	0.3855	8.24
4 ft. x 16 ft.	8	4	9.28	0.2429	2.62
4 ft. x 32 ft.	4	2	18.65	2.1880	11.76

It is interesting to note that the variability increased sharply when plots 32 feet in length were used. The coefficient of variability was less for all of the plots four feet wide than for the plots two feet wide. The results thus indicate that the best plot size for this apparatus was four feet wide and between 8 and 24 feet long.

Although size of plot greatly influenced the accuracy of the application, the number of plots sprayed from one bottle (Table 1) did not significantly change either the standard error or the coefficient of variability. It appears justifiable, therefore, to spray more than one replication from the same bottle.

A typical small-plot test with table beets in which materials were applied with this sprayer is illustrated in Fig. 7. In this case one treatment, consisting of five replications each four feet wide and 14 feet long, was sprayed from one bottle. Notice the beet injury and weed control, both indicators of chemical action.

Walking speed:

The objective was to determine whether or not the operator of the spraying apparatus could change rates of application by changing from one walking speed to another without affecting the accuracy of the spray application.

Five trials were made with the spraying apparatus at both a fast and a slow rate of walking. There were six plots, four by sixteen feet, in each trial. The time for each plot was measured by a second person with a stop watch.

The average time per plot at the slow rate was 7.4 seconds, the standard error of the single observation was .4899, and the coefficient of variability for the thirty plots was 5.87%. The average time per plot at the fast rate was 3.98 seconds, the standard error of the single observation was .3130, and the coefficient of variability was 5.92%.

It may be concluded that the operator was able to about double his speed without a significant change in the coefficient of variability.

Contamination by 2,4–D:

It is generally reported that once a spraying system has been contaminated with a growth regulator such as 2,4–D, other materials should not be used in it unless the sprayer is thoroughly washed with an alkaline solution. It was the objective of this work to determine whether or not contamination of 2,4–D was sufficiently serious with this spraying system that other chemicals should not be subsequently sprayed until it was thoroughly cleansed.

Radishes, a 2,4–D sensitive crop, were planted in rows one foot apart. Plots 20 feet long and four feet wide were layed out allowing for six treatments and four replications with complete randomization within each block. Three of the treatments were 2 pounds of 2,4–D (triethanolamine salt). The other three treatments were water checks, each of which was applied in a different manner following a 2,4–D treatment. The three different methods of handling the water check were as follows: 1) "Sloppy". Water was poured into

the bottle which had contained the 2,4–D and CO_2 was not run through the boom to allow "fogging-out". 2) "Normal". The boom was "fogged-out" once and water from a clean bottle applied. 3) "Careful". One quart of 10% household ammonia was sprayed through the apparatus between the 2,4–D application and the water application. Each plot was sprayed with one bottle, so the effect of contamination would be uniform throughout the replication.

A very heavy stand of purslane was present at the time of spraying, just before emergence of radishes, and showed 2,4–D toxicity as well as the radishes. Visual ratings of the radish and purslane stands were made. The results of these ratings are summarized in Table 2.

Table 2. Visual ratings[1] of 2,4–D injury to radish and purslane.

Treatment	Mean of four replications
2 lbs. 2,4-D	9.0
"Sloppy" water check	3.0
2 lbs. 2,4-D	9.0
"Normal" water check	1.8
2 lbs. 2,4-D	9.0
"Careful" water check	1.0
L.S.D. at 5%	0.7
L.S.D. at 1%	0.9

[1]Rating scale:
1 = no injury
9 = complete kill

The radishes and almost all of the purslane plants were completely eradicated from those plots which received two pounds of 2,4–D per acre. In no case was there visible injury more than four feet from the end of the water check plots. The injury caused to the "normal" and "sloppy" check plots is believed to be due to 2,4–D solution being left in the spray boom. This would explain why it was greater in the "sloppy" plots, where the boom was not "fogged-out". When a boom is "fogged-out", it does not completely clean the boom of all of the 2,4–D, which explains the injury present in the first foot of all the "normal" plots. The injury for all three types of application is illustrated in Figure 8.

It is believed that this experiment points out the unlikelihood of significant contamination in routine screening tests from growth regulators such as 2,4–D when small plots are sprayed with this apparatus, provided the boom is "fogged" to remove actual droplets of the spray before a new chemical is applied.

CONCLUSIONS

A small-plot sprayer which combined the desirable features of existing equipment with the additional advantages of (1) low cost, (2) suitability for plots from 32 to 96 square feet in area and (3) agitation of the spray liquid, has been designed and described.

To help evaluate the equipment, tests were made on size of plot,

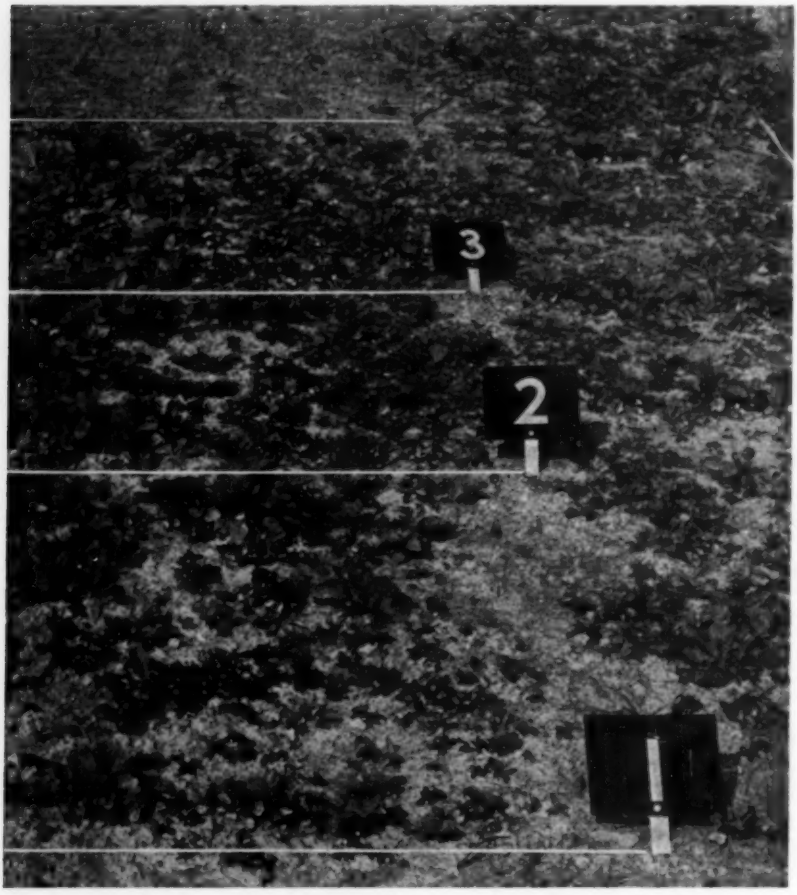

FIG. 8. Results from different methods of "cleansing" the small-plot sprayer following 2,4–D applications.
1. "No fogging", water applied from 2,4–D bottle. ("sloppy")
2. Boom "fogged-out" by passing CO_2 through nozzles for 2 or 3 seconds. Clean bottle used for water. ("normal")
3. One quart of household ammonia sprayed through apparatus. Clean bottle used for water. ("careful")

Background. Two pounds of 2,4–D.
Notice that only in plot 1, is there appreciable 2,4–D contamination.

number of plots per bottle, walking speed, and 2,4–D contamination. Since only one operator was tested the results are not to be taken as absolute. Under the conditions of these tests, however, the following may be concluded: For all plots which were greater than four feet in length more than 80 per cent of the calculated amount of liquid was applied. The coefficient of variability was highest for plots less than 8 feet or more than 24 feet in length. The best size of

plot was four feet wide and 8 to 24 feet long. Two to eight plots were sprayed from one bottle without a significant variation in time required to spray each plot. Dosages could be changed either by changing nozzles or by changing the walking speed used when spraying without influencing the accuracy of the application. 2,4–D did not sufficiently contaminate the sprayer under "normal" conditions to affect more than the first few feet of the plot.

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Herbicides: A New Tool for Use in Studying Soil Physical Properties Affecting Crop Growth[1]

C. L. W. Swanson and H. G. M. Jacobson[2]

With the advent of herbicides, a new tool has been made available for studying the effect of soil physical properties on crop growth. This new tool may be used for solving such problems as "What are the beneficial effects, if any, accruing from cultivation for the control of weeds?" "Is cultivation necessary for maximum production?"

The literature is replete with records of experiments which have led to the conclusion that the main reason for cultivation is to control weeds (4, 5, 7, 12, 13, 17, 18, 19). Many of the textbooks on soils and crops state that cultivation is mainly for the control of weeds (2, 10, 11, 16, 23). In controlling weeds by cultivation, it is pointed out that competition for soil moisture and plant nutrients is reduced. Weeds transpire large amounts of moisture and this loss is eliminated when weeds are destroyed by cultivation.

Much of the work on the value of cultivation was done earlier, and after the general conclusion had been reached that the chief value of tillage is as a weed-control measure, little has been done on the subject in recent years. However, if these earlier experiments are examined closely, one learns that plots were kept weed free by scraping or quick-chopping of the weeds. Mosier and Gustafson (13) describe the method of control used on a weed-free plot as "scraping with a sharp hoe so as to produce practically no mulch". This same method was used by Cates and Cox (5). They state "particular care was to be paid not to stir the soil any more than absolutely necessary". They believed that the principal value of cultivation lies in the killing of weeds and not in the aeration of the soil or the conservation of moisture. They based their conclusions on 125 cultivation experiments conducted in 28 states from 1905 to 1911 in which regular cultivation was compared with scraping with a hoe to destroy weeds. The scraped plots produced on an average 99.1 per cent as much corn as did the cultivated plots.

Soil Factors and Plant Growth

Chief among the soil factors affecting plant growth is the nature of the soil itself, including its physical as well as chemical properties. A great deal of attention has been given to the chemical or fertility status of the soil, but less to its physical nature until comparatively recently.

One of the major reasons for doing research using herbicides for weed control is to produce larger crop yields at less cost. Most of the experiments with herbicides have been concerned with their effects

[1]Contribution from the Department of Soils, The Connecticut Agricultural Experiment Station, New Haven, Conn.

[2]Chief Soil Scientist and Soil Scientist, respectively. Grateful acknowledgment is made to D. B. Downs for assistance in the field and laboratory work.

on weeds and the crop in question, but little attention has been given to the manner in which soil factors may affect production when herbicides are used. The effects of herbicides on the microbiological population of the soil (15) has been investigated.

With herbicides like 2,4–D and others available, weeds can now be controlled, at least initially, without disturbing the soil surface, and the effect of nondisturbance of the soil surface can now be compared with disturbance by cultivation. This allows study of the effect soil physical properties, especially of the soil surface, have on crop growth. Two years results using this approach comparing cultivation versus no cultivation for weed control are now available.

EXPERIMENTAL DETAILS

In order to test the hypothesis that cultivation may be beneficial in ways other than in controlling weeds, corn plots were set up on Cheshire loam soil at the Station's Mt. Carmel Farm in 1948. Characteristics of this Brown Podzolic soil are published elsewhere (9). The following treatments were laid out: (a) Pre-emergence control of weeds in corn with 2,4–D and post-emergence spray 45 days later (non-cultivated); (b) Control of weeds in corn by flaming + cultivation (flamed three times and cultivated once same time as last cultivation of cultivated plots); and (c) Control of weeds in corn by ordinary cultivation methods. All of the plots received equivalent fertilization. Corn was used because it is an excellent indicator of plant nutrient deficiencies, especially nitrogen, phosphorus and potassium. Details of the experiment have been reported elsewhere (21, 22).

WEATHER CONDITIONS, HERBICIDES AND SOIL COMPACTION

In growing crops in the field, unusual weather conditions sometimes have more effect on the crop grown than does the cultural treatment. The years 1948 and 1949 afforded an excellent opportunity for studying the effects of cultivation versus no cultivation on crop growth. During those years, unusually heavy rains fell, packing the ground. Later in the season, it became unusually hot and dry, baking the soil and forming a hard crust on the surface.

The effect of this soil crust was measurable not only in decreased corn yield but also in soil property changes. In 1948, differences in growth did not show up until the corn was about a foot high. In the 2,4–D plots the corn was smaller, lighter green and less vigorous than that on the cultivated plot (22). The differences probably were due to the hard surface crust. Evidently this crust did not allow free circulation of air into the soil, setting up reducing conditions, and resulted in a decrease in the production of nitrates by soil organisms. The plot was practically weed free so no competition was offered for moisture and plant nutrients. There were no observable 2,4–D injuries. Height measurements of the corn 50 days after planting gives an index of its later growth. The 2,4–D treated corn averaged about 3½ inches shorter than the cultivated corn.

Comparison of the corn yields with the physical nature of the soil shows the importance of good soil structure on crop growth. For the surface 2 inches, the arithmetical difference in amount of large pores between the cultivated and the 2,4–D plots was 3.4 per cent more large pores (20.2 and 16.8 per cent, respectively) in the cultivated ones (21). Percentage-wise this is a 20 per cent difference. The yields were 61.5 and 15.2 bushels, respectively, or 46.3 bushels more for the cultivated corn.

Although weeds were well controlled for the first month in the 2,4–D plots, some broadleaf weeds started appearing with grass weeds, being mainly foxtail and crab grass. A second application of 2,4–D at the end of the last cultivation killed most of the broadleaf weeds but the grasses were not affected.

Further evidence that the physical nature of the soil affects crop growth is afforded by the flamed + cultivated plots. The effect of cultivation is reflected in the yield difference of only 8.8 bushels in comparison with the plots cultivated three times. The amount of large pores for the 2 plots is about the same, 21.1 and 20.9 per cent, respectively. Flaming kept weeds down initially but did not kill all of them. It was estimated that after the flamed corn was cultivated that about 10–15 per cent of the ground was covered with grass weeds (mostly crab grass). It was noticed that after the flamed corn was cultivated, it became darker green in color, indicating greater nitrification activity in the soil. This fact, together with the yield differences in comparison with the cultivated plots, indicates the importance of loosening hardened surface soil. Moreover, the early surface crust on the flamed plots appears to be responsible for the retarded growth (7 inches shorter than cultivated corn 50 days after planting).

SECOND YEAR EXPERIMENTS

On the basis of data obtained during 1948 the plot arrangement was revised and moved in 1949 to the Humphrey plot area of the Station Farm which has the same soil type. Flaming of weeds was omitted and scraping with a hoe for weed control similar to that described by Cates and Cox (5) and Mosier and Gustafson (13) was added. In addition, pre-emergence control of weeds with 2,4–D + one cultivation coinciding with the last cultivation for the cultivated plots was included in the experiment. The field plots consisted of four complete randomized blocks. The 1949 studies confirmed the observations made in 1948. In many respects, weather conditions were similar; a wet spring followed by a hot dry summer producing soil crusting.

The following yields, in bushels per acre, using barnyard manure and fertilizers (Figure 1) were obtained: cultivated – 94.6; 2,4–D + one cultivation – 84.7; scraped – 80.3; 2,4–D only – 68.3. The yield differences were not as large as those obtained in 1948, but they followed the same pattern for similar fertilizer treatments – a difference of 26.3 bushels between the cultivated and 2,4–D-only treated corn. No injuries to the corn by 2,4–D were observed. Small-

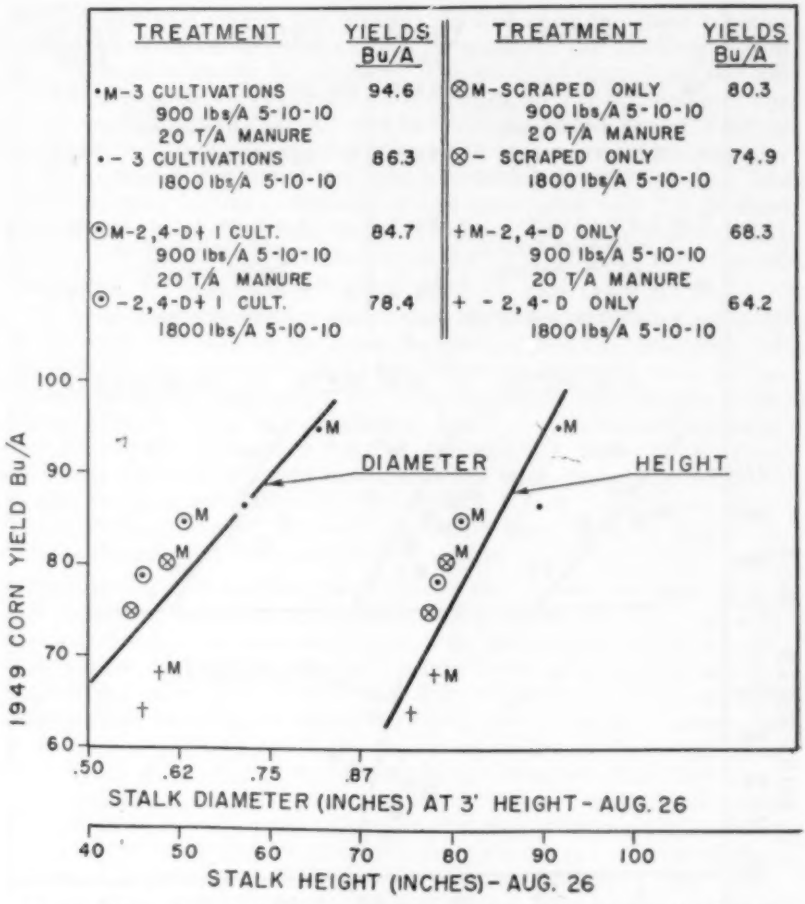

FIG. 1. Effect of method of weed control on the yield and growth of corn grown on a Cheshire loam soil.

er yields were obtained for the plots not treated with barnyard manure, which is to be expected, but the trend of the yields is the same.

Macroporosity differences in the surface 2 inches of soil (cultivated — 19.75 per cent; 2,4–D — 17.76 per cent) on the plots above were not as large as in 1948. This is in line with the corn yield difference, there being 46.3 bushels in 1948 and 26.3 bushels larger yield in 1949 for the cultivated plots. Heights of stalk (91.9 and 78.4 inches, respectively) and diameter of stalk at 3-foot height (0.82 and 0.60 inches, respectively) taken on August 26 (Figure 1) compare favorably with the physical status of the soils in these plots.

In obtaining soil cores for porosity determinations, a record was kept of the amount of force (Figure 2) required to drive the core

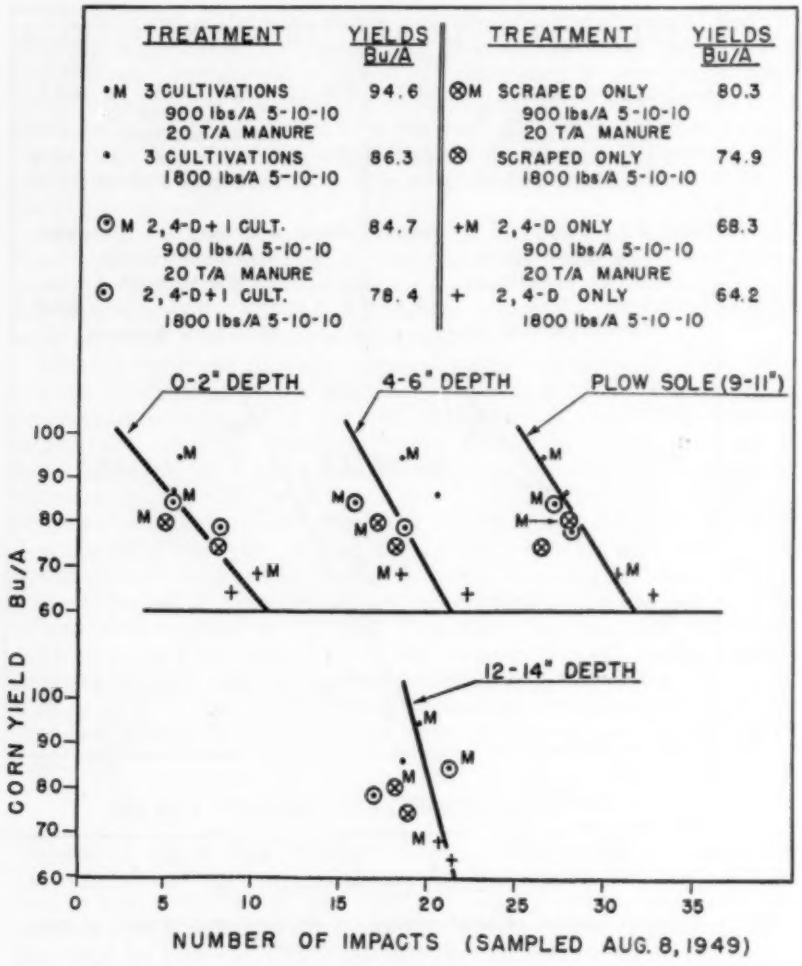

FIG. 2. Comparison of the effect of weed control methods used on the compaction of soil at various depths and on corn yield.

sampler into the soil (20). To penetrate the surface 2 inches of the 2,4–D plots, an average of 10.25 strokes of a 12-pound hammer falling 2 feet were required in comparison with 5.75 strokes for the cultivated plots. Thus 78 per cent more force was required to break through the soil in the 2,4–D plots than in the cultivated ones. Figure 2 shows that the greatest penetration differences were obtained in the 0–2 inch depth.

It is difficult to make comparisons using the scraped plots as having undisturbed soil, since it is practically impossible to use a hoe for cutting off the weeds at ground level without disturbing the soil

surface. For this reason the authors do not consider these plots as having an undisturbed soil surface throughout the growing season as contrasted with the 2,4–D plots. The effect of disturbing the soil surface is seen in a comparison of the yields for the scraped and the 2,4–D + one cultivation (80.3 and 84.7 bushels, respectively). Further evidence of disturbance is shown in the 18.44 per cent macroporosity of the surface 2 inches of soil which is between the high and low macroporosity values obtained for the cultivated and 2,4–D plots mentioned above. Increased height (79.6 inches) and diameter (0.61 inches) of stalk as compared with the 2,4–D plots show the effect of disturbing the surface of the soil (Figure 1).

In 1949, nitrate nitrogen tissue tests (8) were made on August 30 of the corn stalk 4–6 inches from the ground surface. Arbitrary values of 0 for "no nitrate" and 12 for "high test nitrates" were set up. On this basis the reading for the plots receiving only inorganic fertilizers (Figure 3) for the cultivated, 2,4–D + cultivation, scraping, and 2,4–D-only plots were 9.4, 7.3, 6.1 and 6.9, respectively. Plots receiving the same cultural treatments but with manure in addition to the fertilizer gave readings of 11.0, 6.3, 6.4 and 4.4, respectively. These readings are in line with the other data reported above, reflecting the effect of the poor physical nature of soils on plant growth.

Nitrate nitrogen studies were made of the plow depth layer of soil (0.8 inches) at intervals throughout the growing season (Figure 3). It is interesting that immediately after cultivating the 2,4–D + cultivation plots the nitrate nitrogen content went up from 87.9 to 101.4 pounds per acre (July 7 and July 27), respectively. This strongly suggests that breaking of the surface crust permitted free movement of air in the soil and made conditions more favorable for nitrification. These data (Figure 3) are for the unmanured plots. Since manure also improves soil structure, which would favor nitrification, differences in nitrate production for the manure-treated plots were less being 76.5 and 81.1, respectively. In contrast, the cultivated plots decreased from 90.9 to 70.0 pounds per acre for these same dates. The trend for the cultivated plots was from a high to a low amount of nitrates as the season progressed. This suggests that the cultivated corn plants which were growing vigorously (Figure 1) were utilizing the nitrates about as quickly as they became available. On the other hand, the plants in the 2,4–D + cultivation plots were not able to take up the nitrogen as quickly and it was not until later that the plants grew vigorously enough to utilize the available nitrates. For example, on the next sampling (August 8) the nitrate nitrogen content had decreased to 73.4 pounds per acre while that of the cultivated plots was 50.4 pounds per acre. In the case of the 2,4–D-only plots, in the early part of the growing season soil crusts had not formed and nitrate production was about equivalent to that of the other plots (Figure 3). Then later in the season with hotter and drier weather and soil crusting, less nitrates were produced retarding corn growth (Figures 1 and 3). Observations throughout the growing season confirms this.

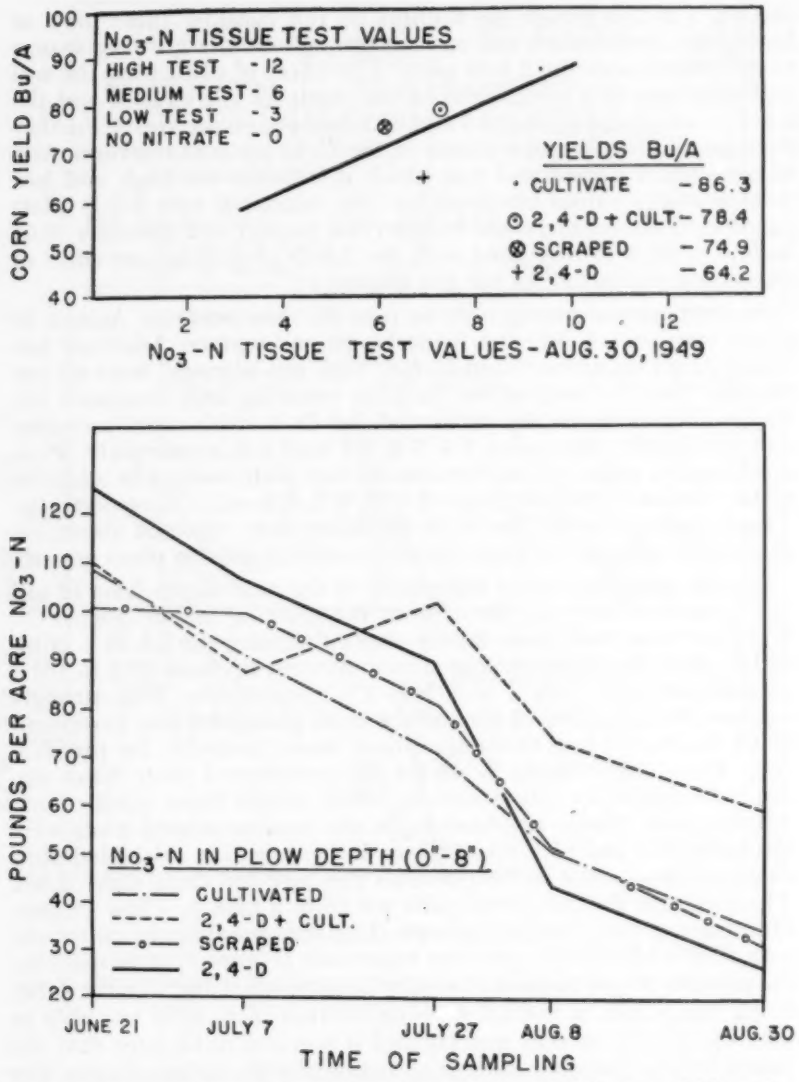

FIG. 3. Nitrate-nitrogen tissue-test values compared with corn yields and method of weed control (upper). Soil nitrate-nitrogen content as influenced by weed control methods (lower).

DISCUSSION

It appears from a review of the early literature that a serious error was made in the research techniques used for studying the effect of weeds on crop production. The early researchers failed to take into account the effect of surface soil compaction on plant growth. The

surface inch or two of the soil was disturbed in scraping off the weeds. In the experience of the authors, it is practically impossible to cut off weeds with a sharp hoe without cutting into the soil. The weeds have to be cut off flush with the soil surface to kill them, and this operation breaks open the soil surface. In fact, what actually happens is that the soil is skimmed which tends to leave a fine soil mulch on the surface. Under these conditions, air can easily enter the soil and reducing conditions would not exist.

With the advent of herbicides, weeds can be controlled without disturbing the soil. This offers a new tool for studying the effect of the physical nature of soils on crop production. In particular, the effect of cultivation on crop response can now be measured more accurately. As with any new tool, care must be taken that it is used properly, as for example, careless use of 2,4–D so that it is injurious to the crop.

The data presented for two seasons are not conclusive proof that cultivation is always desirable. It is believed that the usefulness of cultivation will vary with weather conditions and with soil types. In some seasons it may not be necessary to cultivate. Such a season would be one with rain of low intensity occurring rather frequently supplying adequate moisture for maximum crop production. Thus the soil surface would not be compacted and air could move easily in or out of the soil. In seasons having rains of high intensity which result in packing of the soil, and especially if this is followed by a hot dry period, cultivation would be essential for maximum crop production. The crust formed on the soil surface will need to be broken if reducing soil conditions are to be avoided. On the lighter soils of a sandy texture it is conceivable that the coarse nature of the soil will prevent soil crusting and no benefits from cultivation will accrue. In the heavier soils, hard rains will pack the soil, washing the silt and clay fractions into the soil pores, stopping the movement of air, especially at the soil-air interface.

The pore space of the soil is filled with varying proportions of air and water reciprocally related to each other. When the pores are filled with water, the air is displaced. When the pores in the surface soil-air interface are clogged, the supply of oxygen to higher plants and soil microorganisms is greatly diminished. Soil crusting is an example of clogged pores; when this occurs silt and clay fractions have been washed into the pores by rain water, forming a baked surface on exposure to a hot, drying sun. Unless the crust is broken by cultivation, anaerobic conditions will prevail for air can enter the soil only slowly. Little oxygen will be brought into the soil by rain water for the solubility of oxygen in water is small (0.04 cc/ml). The rate of movement of oxygen through soil pores filled with water is too slow to meet the demands of a normal soil flora. Under such anaerobic conditions, soil-reducing conditions will be produced if a sufficient amount of readily oxidizable organic matter is present and if the soil temperature is favorable for microbiological activity. Under such conditions, some soil constituents become toxic to plants, changing from the oxidized to the reduced state (3) as follows:

Element	*In Oxidized Soil*	*In Reduced Soil*
Carbon	CO_2	CH_4, aldehydes, etc.
Nitrogen	NO_3	NO_2, NH_4^+, N_2
Sulphur	$SO_4^=$	$SO_3^=$, $S^=$
Iron	Fe^{3+}	Fe^{2+}
Manganese	Mn^{4+}	Mn^{3+}, Mn^{2+}

In the case of nitrogen in a reduced soil, ample supplies of nitrates will not be available for maximum growth and nitrogen deficiencies in the plant will show up. The ammonia form of nitrogen can be utilized by some plants but not as quickly nor in so large quantities as nitrates. Nitrites in appreciable amounts are toxic.

In the plots reported on, weeds were not eliminated altogether in the 2,4–D plots. The plots were weed free for the first month and then grass (foxtail and crab grass) started coming in. Later post-emergence applications of 2,4–D practically eliminated the broadleaved variety of weeds. Weed competition, then, was controlled initially and reduced to about 60 to 75 per cent control in the latter part of the season. Techniques are now being worked out to get 100 per cent weed control throughout the season without cultivation.

Results obtained in 1949 for the 2,4–D + one cultivation treatment in comparison with 2,4–D alone indicate that a combination of herbicides plus cultivation would give maximum crop production, at least for seasons of high intensity rains which pack the soil surface. In seasons of low intensity and abundant rainfall, cultivation might be dispensed with on the lighter soils, and a combination of herbicides used for controlling weeds. This might be a pre-emergence herbicide like 2,4–D to control the weeds for the first month, then using a post-emergence spray of 2,4–D to kill the broadleaved weed varieties, and some other herbicide for controlling the grass weeds. At the present time, however, a herbicide for killing grass types of weeds in cultivated crops like corn is not available.

It is quite likely that one explanation for the diversity of results (1, 6, 14, 24) obtained where 2,4–D was applied and not cultivated, in contrast to 2,4–D + cultivation can be attributed to soil factors. For valid comparison of results, the soil type should be included in the description of the experiment and such information as is available regarding its physical characteristics. It would be especially helpful in analyzing the results of an experiment if nitrogen deficiencies, if they occurred, were noted. It is altogether possible that, in many instances, 2,4–D has been blamed for lower yields which correctly should be attributed to soil factors.

SUMMARY

A review of the literature on the early work of the effect of cultivation compared with no cultivation (plots kept weed-free by scraping) on corn revealed that in the scraping plots the soil surface had been disturbed. This disturbance of the soil allowed an interchange of soil-air gases, especially oxygen, at the soil-air interface. It is believed that these earlier experiments were not fair comparisons

between cultivated and non-cultivated corn plots. With the advent of herbicides, a new tool is available for checking on the effect of cultivation versus no cultivation.

Corn plots were set up on a Cheshire loam soil in 1948 and 1949 to test the significance of cultivation on corn growth. During those years, unusually heavy rains fell, packing the soil. Later in the season, it became unusually hot and dry, baking the soil and forming a hard crust on the surface.

Comparisons were made in 1948 between cultivation, pre-emergence 2,4–D, and flame + one cultivation (coincided with last cultivation of cultivated plots) treatments for weed control; in 1949, these treatments were cultivation, scraping, 2,4–D only, 2,4–D + one cultivation. Post-emergence applications of 2,4–D were made about 50 days after the initial application.

Comparison of the corn yields with the physical nature of the soil shows the importance of good soil structure on crop growth. Yields in 1948 for cultivated versus 2,4–D treated plots were 61.5 and 15.2 bushels, respectively; in 1949, they were 94.6 and 68.3. In 1948, the cultivated plots had 20 per cent more large soil pores in the surface 2 inches than the 2,4–D treated plots; in 1949, this difference was 11 per cent.

The effect of cultivation in breaking the soil crust is brought out by cultivating the flamed plots once corresponding with the last cultivation of the cultivated plots. The flamed corn yielded only 8.8 bushels less than the cultivated corn. In 1949, plots treated with 2,4–D + one cultivation yielded 9.9 bushels less than the cultivated ones. In 1948, the flamed corn became darker green in color after cultivation, indicating greater nitrification activity in the soil. In 1949, nitrate nitrogen studies of the 0–8 inch depth showed that immediately after cultivating the 2,4–D + cultivation plots the nitrate nitrogen content went up from 87.9 to 101.4 pounds per acre.

Penetrometer studies in 1949 revealed that 78 per cent more force was required to break through the surface 2 inches of soil in the 2,4–D treated plots than in the cultivated ones.

Weeds in the 2,4–D plots were controlled initially for the first month. It was estimated that weed competition was reduced to about 60 to 75 per cent control in the latter part of the season.

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Plant Hormone Activity of Substituted Benzoic Acids and Related Compounds

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ZIMMERMAN[1] has summarized the plant hormone activity of trichlorobenzoic acid and various substituted derivatives. The effects have been found to be formative in nature.

METHOD AND DATA

The experiments reported here are concerned with hormone activity of the tetrachloro- and pentachlorobenzoic acids and related compounds. Table 1 reports the activity as determined by the application of water suspensions or emulsions of these compounds to the primary leaves of snap beans in the greenhouse and measurement of the subsequent growth of the trifoliate leaves. Applications were made to primary leaves after they unfolded and before the beginning of development of trifoliate leaves, using 4–6 plants for each concentration. Weight of the latter was determined at the end of approximately two weeks and expressed as percentage of the check. The mono- and dichlorobenzoic acids are also included for comparison.

Table 1. Growth inhibiting activity of various chlorinated benzoic acids on bean plants.

Compounds and formulation	Concentration (per cent)	Growth (per cent of check)
p-chlorobenzoic acid—sodium salt	0.25	100.0
3,4-dichlorobenzoic acid—sodium salt	0.25	88.8
2,3,4,5-tetrachlorobenzoic acid—wettable powder	0.01	23.0
	0.25	(dead)
2,3,4,5-tetrachlorobenzoic acid—emulsion	0.25	0.0
2-ethylhexyl-2,3,4,5-tetrachlorobenzoate—emulsion	0.25	0.0
Pentachlorobenzoic acid—wettable powder	0.01	2.4
Pentachlorobenzoic acid—wettable powder	0.25	(dead)
Pentachlorobenzoic acid—emulsion	0.25	(dead)
Pentachlorobenzal chloride—emulsion	0.25	82.0
Pentachlorobenzyl alcohol—emulsion	0.25	9.0
Pentachlorobenzyl chloride—emulsion	0.25	100.0
Pentachlorobenzene sulfonic acid—emulsion	0.20	27.0
Pentachlorobenzene sulfonyl chloride—emulsion	0.25	27.0
Tetrachlorobenzene sulfonyl fluoride—emulsion	0.25	29.0

Emulsions of tetra- and pentachlorobenzoic acids were applied to growing cotton plants in pots in the greenhouse. The plants were 12 to 18 inches in height. Applications were made by spraying two plants on a rotating turntable with a Devilbiss atomizer (type CM) using 100 mls. of the water suspension or emulsion. Data on cotton are given in Table 2 and were obtained by actual counts of the numbers of leaves at the time of application and at the periods noted

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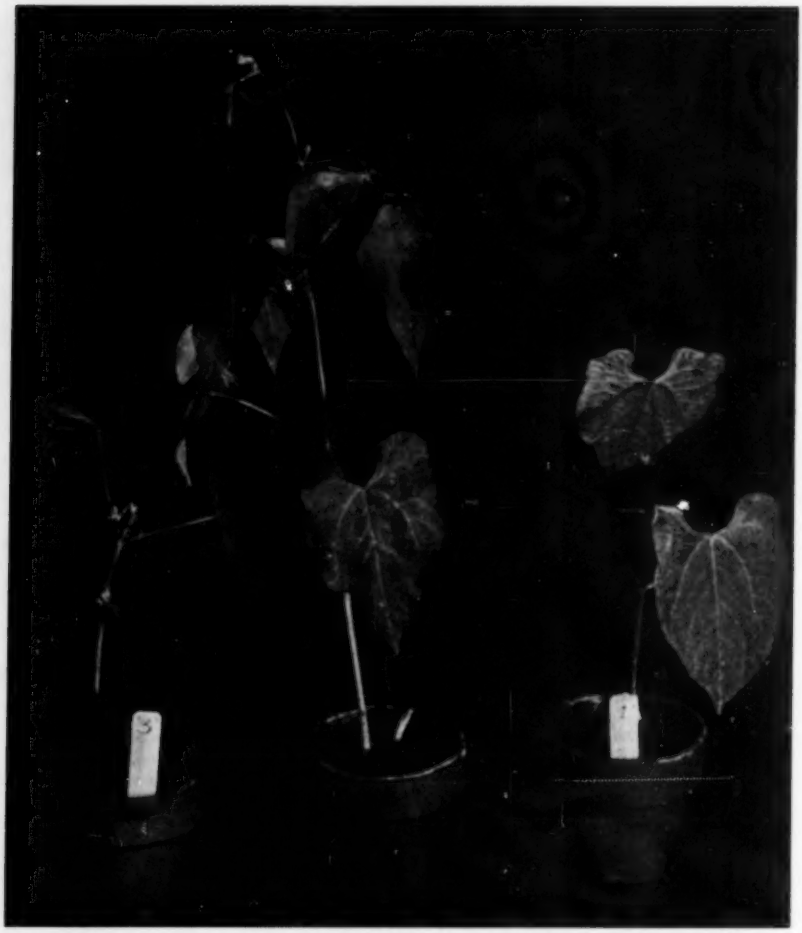

FIG. 1. Inhibition of growth of snap beans by tetrachlorobenzoic acid, 0.01% (left), and pentachlorobenzoic acid, 0.01% (right), fifteen days after treatment. Untreated check in center.

in the table. The inhibition effect on snap beans is illustrated in Figure 1.

The effectiveness of tetra- and pentachlorobenzoic acids for pre-emergence weed control was evaluated in greenhouse tests using flats 9 by 13.5 inches in which the crops had been planted. The weed seed was sown on the surface of the flat after planting the crop and lightly covered. Applications were made the same day as planting using a small Devilbiss atomizer No. 15 to apply 20 mls. of the emulsion directly to the soil surface. Flats were watered 18 hours after planting and treating. Counts were made on the number of weeds emerged per flat at the end of approximately two weeks and data are recorded in Table 3.

Field tests were also conducted with the emulsions by spraying 4′ x 4′ plots (separated by boards) with a knapsack sprayer at the rates indicated. Applications were made within 1–3 days after preparation of the soil. Data were obtained by actual counts of the numbers of weeds at the end of six weeks.

DISCUSSION

Practically no growth inhibition was obtained with p-chlorobenzoic acid and 3,4–dichlorobenzoic acid. The formative effects of the tri-substituted benzoic acids have been referred to but no tests were made for a direct evaluation here of their growth inhibiting properties. The tetra- and pentachlorobenzoic acids completely inhibited growth of beans plants at .25% with complete killing of the plant in some tests. The 2–ethylhexyl–2,3,4,5–tetrachlorobenzoate was active, pentachlorobenzyl chloride possessed no activity, while pentachlorobenzyl alcohol exhibited only moderate activity. Formative effects of these compounds were not pronounced on the plants used in these tests. Highly chlorinated benzene sulfonic acids and related compounds showed similar effects.

Table 2. Growth inhibition and defoliation action of 2,3,4,5–tetrachlorobenzoic acid and pentachlorobenzoic acid applied as emulsions to greenhouse-grown cotton plants.

Compound	Concentration (per cent)	Defoliation (per cent)	Number of new leaves (2 plants)	
			18 days	36 days
Pentachlorobenzoic acid	0.025	0.0	1	13
	0.05	8.0	0	13
	0.1	50.0	0	11
	0.2	17.5	0	0
Check	0.0	0.0	6	8
Tetrachlorobenzoic acid	0.05	8.0	2	9
	0.1	21.0	3	12
	0.2	45.0	1	6
	0.4	38.0	4	16
Check	0.0	0.0	1	14

Table 3. Pre-emergence weed control tests in greenhouse flats with 2,3,4,5–tetrachlorobenzoic acid and pentachlorobenzoic acid emulsions. Average of two separate experiments of one flat each.

Compound	Rate/A lbs.	Weeds[1] (per cent check)	Crop injury				
			Corn	Soy bean	Lima bean	Snap bean	Cotton
Tetrachlorobenzoic acid	5	59.0	None	Stunted	Stunted	Stunted	None
	10	14.5	None	Stunted	Stunted	Stunted	None
Pentachlorobenzoic acid	5	10.5	None	Stunted	Stunted	Stunted	Stunted
	10	6.0	None	Stunted	Stunted	Stunted	Stunted

[1] *Chenopodium album* and *Amaranthus hybridus*.

Tests on cotton indicated some defoliant action with tetra- and pentachlorobenzoic acid but the leaves were frozen on at the high doses (.2 & .4% respectively) before satisfactory defoliation was obtained. Pentachlorobenzoic acid gave complete inhibition of growth for 18 days at dosage ranging from 0.05% to 0.2% and for 36 days at a dose of 0.2%.

The tetrachlorobenzoic acid did not inhibit the growth of cotton to any significant extent. No kill of cotton plants was obtained at any dose. Subsequent field tests at Weslaco, Texas and Blackville, South Carolina have indicated that pentachlorobenzoic acid has little if any growth inhibiting properties on large mature defoliated plants.

Pentachlorobenzoic acid gave good pre-emergence weed control at 5 pounds per acre but injury was noted on cotton. Other tests also produced injury on lima, snap, and soy beans. The tetrachloro acid gave good control of weeds at 10 pounds per acre with no injury to corn and cotton. Some injury was noted on beans in other tests. No control of crab-grass was obtained in other tests. These results were confirmed in small scale field tests.

CONCLUSIONS

2–ethylhexyl–2,3,4,5–tetrachlorobenzoate, 2,3,4,5–tetrachlorobenzoic acid, and pentachlorobenzoic acid give inhibition of growth of bean plants at less than 0.25%. Pentachlorobenzoic acid completely stops growth of cotton plants at 0.2% in the greenhouse but was relatively ineffective on large defoliated cotton. Tetrachlorobenzoic acid was much less effective on this plant. Good pre-emergence weed control was obtained in greenhouse tests with pentachlorobenzoic acid at 5 lbs. per acre with no injury to corn and with tetrachlorobenzoic acid at 10 lbs. per acre with no injury to corn and cotton. Other applications of these compounds are under study.

Comments on Selective Herbicides for Kale and Broccoli

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EXPERIMENTS were conducted during 1950 and 1951 for the purpose of finding a selective herbicide for kale and broccoli. Chemicals tested were KOCN, IPC, chloro IPC, E. H. 1, PMA, and CMU. Materials were used alone and in combination, also without and with wetting agents such as Vatsol K, Igepal, and Glim.

Weeds involved were red root pigweed *(Amaranthus retroflexus)*, galinsoga *(Galinsoga ciliata)*, carpetweed *(Mollugo verticillata)*, purslane *(Portulaca oleracea)*, and lambs quarters *(Chenopodium album)*.

The most promising of the herbicides tested was KOCN. Both broccoli and the Dwarf Blue Curled Scotch variety of kale could be safely sprayed with 1.0 or 1.5 per cent KOCN at a rate of 72 gallons per acre, provided the crop plants had developed true leaves. Hanover kale, smooth leaved, was not resistant. Red root, galinsoga, and carpetweed were effectively controlled if treated when small. Regardless of size, KOCN did not control purslane and lambs quarters.

Additions of wetting agents and other herbicides to KOCN sprays in attempts for better weed control were unsuccessful from the standpoint of both crop injury and weed kill.

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What to Call It?

THE NORTH CENTRAL CONFERENCE has recognized the problem of standardization of herbicide nomenclature and has an active committee at work. While it is easy to criticize a few of the decisions made by the North Central Conference, at least they have made a constructive attempt at agreement. Most of the other conferences have talked about the "mess" but have not taken positive action. Is not finding a solution to this problem an appropriate function, however, of an organization of wider scope than just one regional conference? Should not the officials of the Association properly be charged with the responsibility of setting up suitable machinery for accomplishing national and international standardization on "what to call it"?

In our opinion, one of the very important contributions the Association of Regional Weed Control Conferences could make to the field of weed control would be in standardizing the nomenclature of herbicides.

WEEDS First Editorial Board

The accompanying pictures and sketches are presented to give readers a better idea of who germinated WEEDS. As the conferences choose new board members we will keep you informed.

W. A. HARVEY
Western Weed Control Conference

"Bill" Harvey, Extension Weed Control Specialist, Botany Division, University of California, Davis, is active in both the Western and the California Weed Conferences. He was trained at Missouri and Iowa State. For seven years was an agronomist for the Washington State College doing full time weed control work in the Yakima Valley.

DR. E. P. SYLWESTER
North Central Weed Control Conference

"Dutch" Sylwester is head of the State College Seed Laboratory and is in charge of extension weed control for all Iowa. He was Minnesota farm-reared and migrated to Iowa for advanced training in Botany and Plant Pathology. He is a past president of the North Central Conference and is very active in conducting Iowa Pest Control Clinics.

DR. H. L. YOWELL
Northeastern Weed Control Conference

Howard Yowell heads the agricultural research program, plus several other major research phases, of the Standard Oil Development Company. He has been active in the Northeastern Conference and in the Regional Association. WEEDS has delegated him the task of handling the advertising. Before moving to the vicinity of the Big City, Howard hailed from Southern Illinois. He obtained his Ph.D degree from Ohio State.

DR. E. C. TULLIS
Southern Weed Conference

Edgar Tullis has recently gone to Camp Detrick from Beaumont, Texas where he held a U.S.D.A. appointment. He received much of his training in pathology with advanced training at Nebraska and Michigan State. A past president of the Southern Conference, and has been very active in spark-plugging sales of WEEDS subscriptions to his Southern colleagues.

DR. R. L. LOVVORN
Association of Regional Weed Control Conferences

Roy Lovvorn, Division of Weed Investigations, U.S.D.A., has been an active participant in meetings of all four of the regional conferences. His agronomy training was obtained in Alabama, Missouri, and Minnesota. He was primarily concerned with pasture improvement in North Carolina before accepting his present position as head of the Weed Division. Roy is handling all the detail of subscriptions for WEEDS.

DR. R. D. SWEET
Temporary Editor

"Bob" Sweet, Department of Vegetable Crops, Cornell University, helped organize the Northeastern Conference and has been active in the Association of Regional Conferences. He was trained in Ohio and at Cornell as a horticulturist. As temporary editor of WEEDS he is increasing his training but along lines somewhat different from horticulture.

News from the Conferences

F. L. Timmons should have an interesting story to tell on his return from India. He is studying the possibilities of chemical controls for Kans grass *(Saccharum spontaneum)*, a species of wild sugar cane that has taken over several million acres of land in central and north central India. The World Bank has loaned the Indian Government ten million to combat the pest. He will travel under the Point IV program of the office of Foreign Agricultural Relations.

The Western Canadian Weed Control Conference met in Vancouver, B. C. on November 27 and 28, 1951, with 136 registered attendance. Their program covered a wide range of topics, including fundamental research and control measures for weeds in grains, range lands, horticultural crops, etc. At the banquet, F. L. Timmons was guest speaker.

Courtesy Agricultural Chemicals

New officers of the Northeastern Weed Control Conference
Left to right: R. H. Beatty, Vice-Pres., C. E. Minarik, Pres., W. C. Jacob, Sec'y.-Treas., H. L. Yowell, WEEDS Editorial Board.

The North Central Weed Control Conference will move north of the border to Winnipeg for its 1952 meeting. At their Oklahoma City meeting in December they voted to support a national weed meeting, and to continue their regional conference on an annual basis. Dr. K. P. Buchholtz, their president for 1952 has appointed Dr. R. S. Dunham, Agronomy Department, University of Minnesota, as the WEEDS Editorial Board representative for the North Central Conference.

At the Hotel New Yorker early in January the Northeastern Conference held its sixth annual meeting. Registered attendance was about 375. This represents another year in which attendance increased over that of the previous conference. The consensus of opinion seemed to be that the brush part of the program was the most popular from the standpoint of those in attendance. Dr. C. E. Minarik is the new president.

BOOK NOTES

By CAROL H. WOODWARD

WEED SEEDLINGS. Anna P. Kummer. 435 pages. University of Chicago Press, 1951. $5.00.

Finely detailed drawings of the seedlings of 300 broad-leaved herbaceous weeds from germination through the fifth leaf, a description of each, and a comprehensive key to all.

PLANT GROWTH SUBSTANCES. Edited by Folke Skoog. 476 pages, University of Wisconsin Press, Madison. 1951. $6.00.

Symposium by nearly forty leading research scientists in American institutions dealing in part with weed control substances and their physiological and practical effects.

HERBERT H. DOW, PIONEER IN CREATIVE CHEMISTRY. Murray Campbell & Harrison Hatton. 168 pages. Appleton-Century-Crofts, New York. 1951. $3.50.

Biography of the founder of a firm which has become one of the principal manufacturers of herbicides.

ELEMENTS OF PLANT PROTECTION. Louis L. Pyenson. 538 pages. Wiley, New York. 1951. $4.96.

Control of plant diseases, insect pests, injurious animals and birds, as well as weeds, with chapters on application equipment.

AN ILLUSTRATED MANUAL OF CALIFORNIA SHRUBS. Howard E. McMinn. 663 pages. University of California Press, Berkeley. 1951. $6.50.

Reprint by offset of the edition of 1939, containing keys and descriptions for the identification of more than 1,000 woody plants of the Far West.

AMERICAN WILDLIFE AND PLANTS. Alexander C. Martin, Herbert S. Zim & Arnold L. Nelson. 500 pages. McGraw-Hill, New York. 1951. $7.50.

Geographical range and description given for each animal and plant, with notes in the plant section on the predators of each plant species; in the animal section on the foods of each animal mentioned.

DECIDUOUS FORESTS OF EASTERN NORTH AMERICA. E. Lucy Braun. 596 pages. Blakiston, Philadelphia. 1950. $10.00.

A reference work culminating 25 years of conscientious field work and research, covering geological considerations in forest development as well as recent and present-day aspects of the areas, with a bibliography of some 550 titles.

PLANT NAMES SIMPLIFIED. A. T. Johnson & H. A. Smith. 120 pages. Collingridge, London; Transatlantic Arts, Hollywood-by-the-Sea, Florida. 1951. $1.80.

Explanation and pronunciation of some 4,500 names of plants that are in cultivation.

TENTH SHORT COURSE ON ROADSIDE DEVELOPMENT. 186 mimeographed pages. Department of Landscape Architecture, Ohio State University, and Ohio Department of Highways, Columbus. 1951. No charge.

Papers given at the April 1951 course at Ohio State University, among them considerations of roadside weed control in its relation to safety, beauty, and wildlife preservation.

BIBLIOGRAPHY OF WEED INVESTIGATIONS

for July, August, and September 1951

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Prepared By *Division of Weed Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture*

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Division of Weed Investigations does not assume responsibility for the subject matter cited.

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